NEW ENGLAND INTERCOLLEGIATE GEOLOGICAL CONFERENCE

GUIDEBOOK

56th Annual Meeting

OCTOBER 2 - 4, 1964

AT

BOSTON COLLEGE
CHESTNUT HILL, MASSACHUSETTS

NEW ENGLAND INTERCOLLEGIATE GEOLOGICAL CONFERENCE

Guidebook to Field Trips in the Boston Area and Vicinity

56th Annual Meeting
October 2-4, 1964

held at

Boston College

Chestnut Hill Massachusetts

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LEADERS:

Clifford A. Kaye	- Geologist, U.S. Geological Survey
Robert L. Nichols	- Professor of Geology, Tufts University
Robert F. Boutilier	- Professor of Geology, Boston University
Dabney W. Caldwell	- Professor of Geology, Wellesley College
Cornelius S. Hurlbut	- Professor of Mineralogy, Harvard University
Priestley Toulmin, III.	- Geologist, U.S. Geological Survey
Norman P. Cuppels	- Geologist, U.S. Geological Survey
Newton E. Chute	- Professor of Geology, Syracuse University
Kenneth Bell	- Geologist, U.S. Geological Survey

EDITOR AND CONFERENCE ORGANIZER

James W. Skehan, S.J.	- Professor of Geology, Boston College

CONFERENCE COORDINATORS.

Lydia M. McCarthy	- Department of Geology Staff,
Maryellen McCluskey	Boston College

NEIGC MEETINGS, 1964, CHESTNUT HILL, MASSACHUSETTS

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ILLUSTRATIONS

INTRODUCTION

James W. Skehan, S.J., Boston College

The Boston Basin and adjacent areas have a wide range of geologic features. In planning the 1964 field trips of the 56th Annual Meeting of the New England Intercollegiate Geological Conference, the Editor and Organizer wished to offer to the large number of participants an opportunity to study features truly representative of the geology of eastern Massachusetts.

Eight field trips will be presented for a full day on Saturday and abbreviated field trips to the same areas will be conducted on Sunday. The interested student o Earth Science may develop for himself a representative composite picture of the geology of the Boston Basin and of the metamorphic and igneous rocks outside the Basin proper by a synthesis of information contained in this guidebook. Each field trip leader has presented a general discussion of the relation of his area of special study to the geology of the region. He has also presented a discussion of certain details of selected outcrops which have been chosen to illustrate some of the genera features. Each has chosen to present the kind of road log which he considers best suited to a study of the area in question. It may be noted that two variations in stratigraphic designation are used by various authors both of which are proper usage; the one approved by the U.S. Geological Survey for publications by its members and the other approved by the Committee on Stratigraphic Nomenclature of the Geological Society of America.

This printed outline of the geology of the areas selected for special study by this Annual Meeting is presented with the expectation that it will benefit not only the Conference participants under the personal guidance of the Leaders but also thos geologists, teachers of Earth Science, and the interested public who, in the absence of personally guided tours by the Leaders, may wish to use the guidebook to visit and understand the geological features described herein.

The Editor and Organizer of this Conference wishes to acknowledge his gratitude to the following persons who have helped in a special way to make the 56th Annual Meeting possible: Very Rev. Michael P. Walsh, S.J., President of the Host Institution, who invited the Conference to the Boston College campus; all the highly qualified and busy field trip leaders from neighboring institutions and from the United States Geological Survey who have generously shared of their time and scientific knowledge to make the geology of this area better understood; Miss Lydia M. McCarthy, Administrative Assistant, who attended to the innumerable arrangements connected with a meeting of this size; Miss Maryellen McCluskey, who typed the multiliths of the manuscript for publication and who assisted in coordinating arrangements; Mrs. Alfred E. Wier, who assisted in proofreading the manuscript; Profs. John J. Rodgers, Yale University and Alonzo W. Quinn, Brown

University whose assistance with advice and mailing were most helpful; Profs. Emanuel G. Bombolakis, George D. Brown, Jr., and Mrs. William Schromm of the Boston College Geology Teaching Staff, and the Geology Club led by President Charles G. Legarde, who were most helpful in connection with the field trips themselves; Rev. Francis B. McManus, S.J., Secretary of the University, and his staff, who handled the campus arrangements; and all the many others who assisted in many ways.

TRIP A - Saturday

GREATER BOSTON GEOMORPHOLOGY

Robert L. Nichols, Tufts University*

Foster Street Stop, Brighton, Newton Quadrangle, Massachusetts; 0.3 mile north of Chestnut Hill Reservoir.

To be seen:

(1) outcrop of Roxbury conglomerate
(2) glacial grooving and striations
(3) dominant orientation of striations and grooves is N.27° - 35° W
(4) curved striations and striations to N.65° W. caused by local deflection of ice flow by rock obstructions

Discussion:

(1) the N.10°-35° W. striations of the Boston area produced by late Wisconsin, post-drumlin glaciation
(2) nature of deflection of ice flow by small rock obstruction

Parker Hill Drumlin Stop, Boston, seen from Boylston St., Brookline Village.

To be seen:

(1) shape and orientation of drumlin (Fig. 1)
(2) drumlin till
(3) oxidation of till
(4) position of bedrock high

Discussion:

(1) significance of depth of oxidation
(2) age of drumlin
(3) effect of later ice having different flow direction on drumlin shape

Boston Government Center Stop, (the foundation excavation for the new City Hall if this is still open; otherwise some other excavation in the area).

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* The co-leader of this field trip, C.A. Kaye, has been prevented, by pressures of other commitments, from sharing the authorship of this guide.

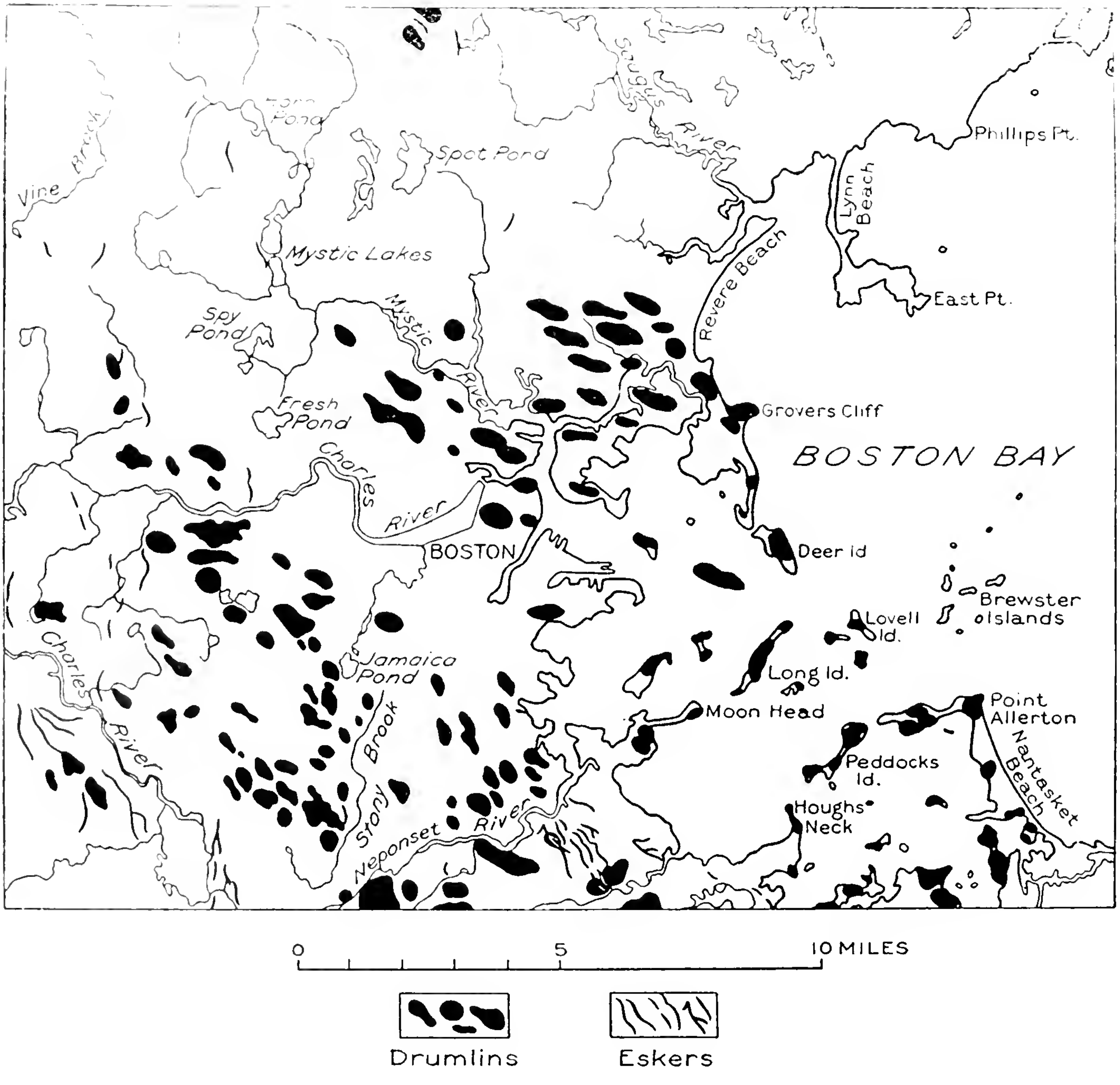


Figure 1. Distribution of drumlins and eskers in the Boston area (Fig. 5 from LaForge, Laurence, 1932, Geology of the Boston Area, Massachusetts: Geological Survey Bull. 839).

To be seen:

(1) stratigraphic sequence (Fig. 2)
  d. sandy clay and clay
  c. clay
  b. oxidized gravel
  a. very compact clay

(2) folding and faulting

(3) unconformity above Clay c. (above)

Discussion:

(1) age and correlation of deposits (Table 1)
(2) depositional environment
(3) nature of deforming forces
(4) sea-level fluctuations

Snake Island Stop, Winthrop, Massachusetts, Hull Quad., Massachusetts (Figs, 3, 4, 5).

The following geological features can be seen:

(1) boulder pavement
(2) marine cliff
(3) till
(4) off shore peat
(5) beach
(6) marsh

Discussion:

(1) lost islands
(2) simple flying bar
(3) sub-aerial and submarine flying bars
(4) winged drumlin
(5) winged flying bar

Shirley Gut Stop, Boston, Massachusetts, Hull Quad., Massachusetts (Figs. 3, 6, 7).

Discussion:

(1) Point Shirley, Deer Island
(2) Colonial and recent history
(3) closing of Shirley Gut
(4) hydraulic and longshore currents
(5) growth of spits

Nixes Mate Stop, Boston, Massachusetts, Hull Quad., Massachusetts (Fig 3).

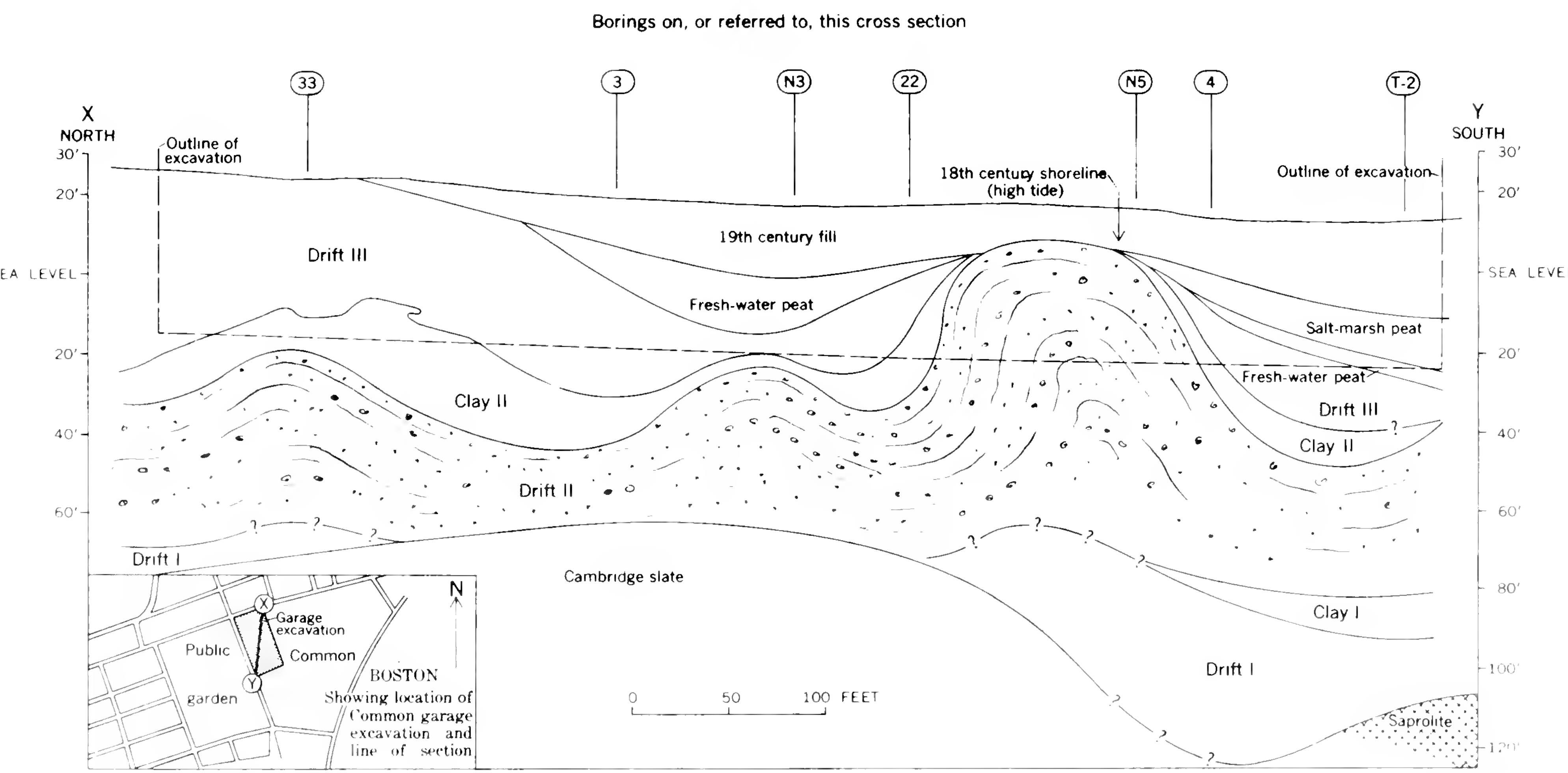


Figure 2. North-south geologic cross section, lower Boston Common, at site of underground garage (Fig. 34.1 from Kaye, C.A., 1961, Pleistocene stratigraphy of Boston, Mass.: U.S. Geological Survey Prof. P. 424-B, p. 73-76).

Deposit	Description	Remarks	Depth of oxidation [1]	Direction of ice flow	Relative sea level [2]
Drift IV	Boston basin: mostly outwash. Uplands: till and outwash.		In outwash generally less than 4 ft, in till 1½ ft.	S. 10°-35°E	Lower than −30 ft.
Oxidation of Clay III					Lower than −35 ft.
Clay III	Marine clay. More than 180 ft thick under lowlands. Precompressed to depths of 70 ft.	Possibly deposited when ice front was not far from Boston.	3 ft under Drift IV, 10 ft elsewhere.		Found to altitude +25 ft in Boston. Contains fairly deep water fauna suggesting sea level above +50 ft.
Oxidation of Drift III					Lower than − 20 ft.
Drift III	The drumlin till.	Very compact in drumlins; less compact as ground moraine.	Maximum 65 ft in drumlins; where less, oxidized zone probably eroded by Late Wisconsin ice.	S. 60°-80° E	Possibly above +50 ft.
Clay II	Probably marine.	Probably source of shells in Drift III. May have been deposited during advance of Iowan ice.	None where recognized. May have been eroded.		Possibly about +50 ft.
Oxidation of Drift II					−45 ft (?)
Drift II	Mostly gravelly outwash; some associated till.	Folded in places.	65 ft or more in sand and gravel. Some pebbles decomposed	Unknown.	Below −75 ft.
Clay I	Probably marine.	Recognized only in borings	None noted; possibly eroded.		−45 ft or above.
Drift I	Very compact till.	Recognized with certainty only in deep borings.	None noted.	Unknown.	(?)

[1] Oxidized zone of all units but Drift IV was subject to erosion by later ice.
[2] Altitudes refer to present mean sea level.

Table 1. Pleistocene deposits of Boston, Mass. (Table 1 from Kaye, C.A., 1961, Pleistocene stratigraphy of Boston, Mass.: U.S. Geol. Survey Prof. P. 424-B, p. 73-76).

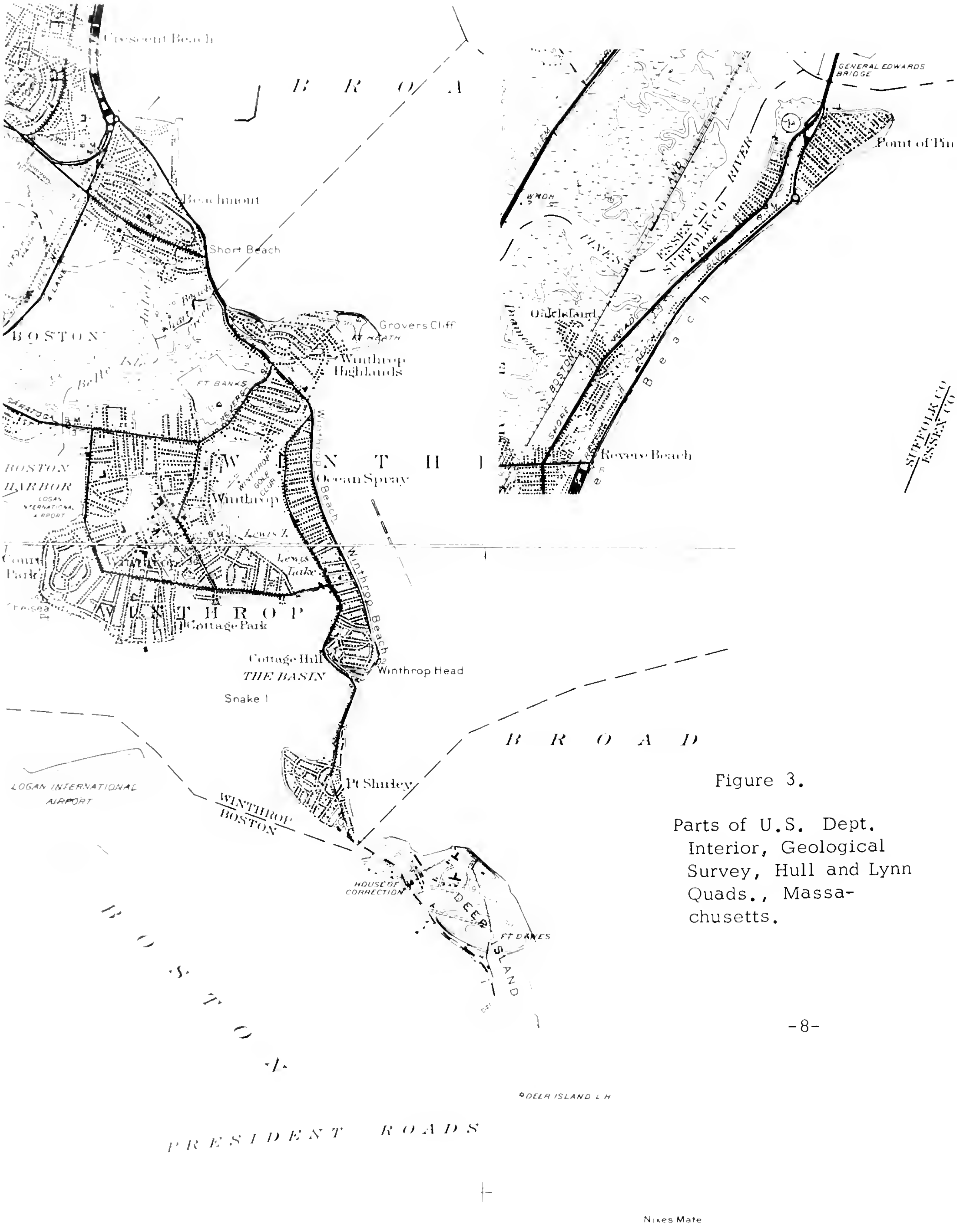


Figure 3.

Parts of U.S. Dept. Interior, Geological Survey, Hull and Lynn Quads., Massachusetts.

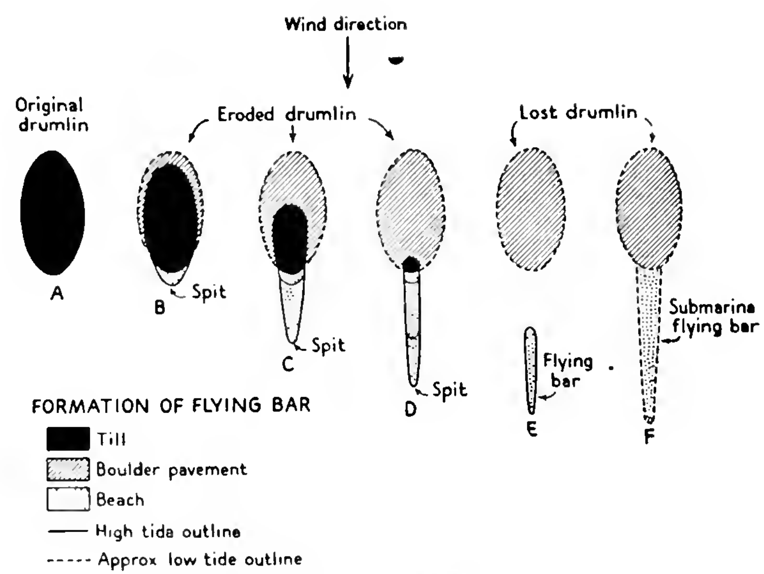


Figure I. Formation of a simple flying bar.

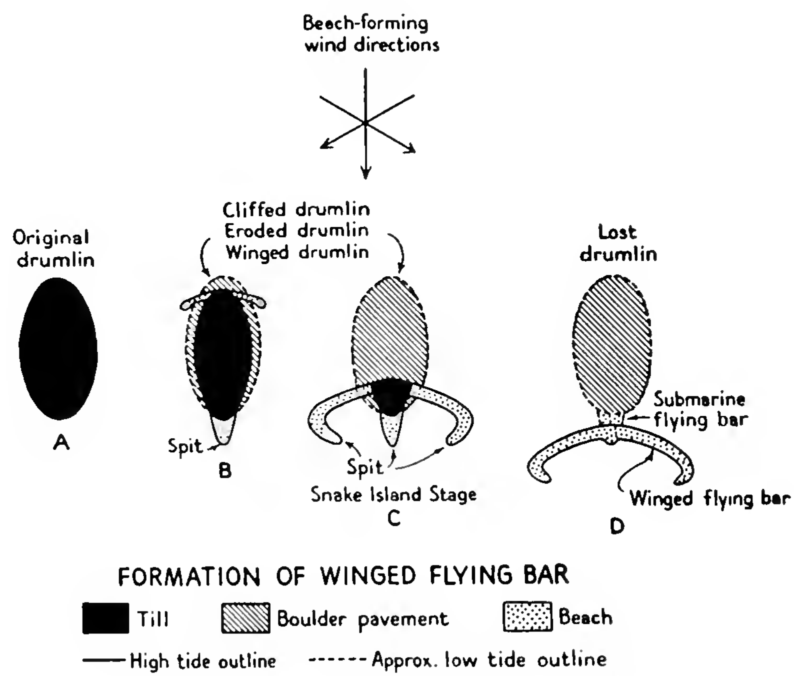


Figure 4. Formation of a winged flying bar.

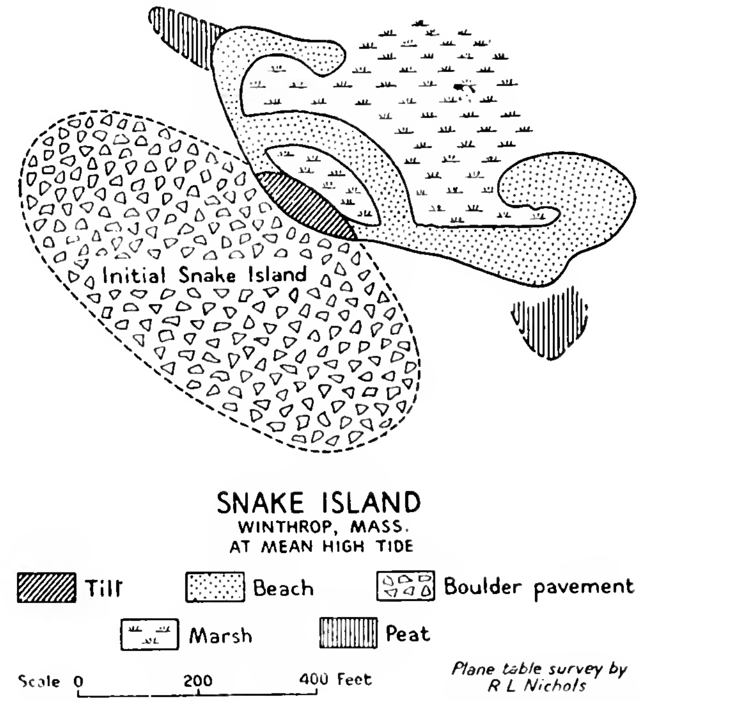


Figure 5. Snake Island, Winthrop, Mass., in Boston Harbor. A potential winged flying bar.

after R. L. Nichols

Hull, Mass.
Quad., U. S. G. S.

A sand bar formerly attached to an island becomes a flying bar when the island is destroyed. Snake Island in Boston Harbor is an excellent example of a potential flying bar.

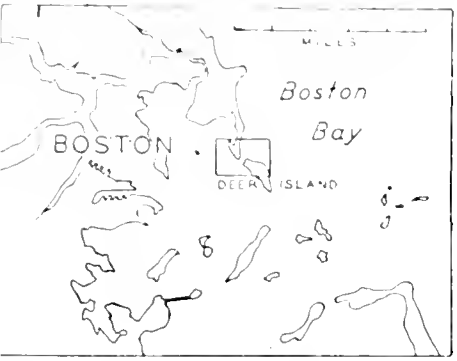


Fig 6a. Index map of Boston Harbor, [M]assachusetts. Area considered in text outlined

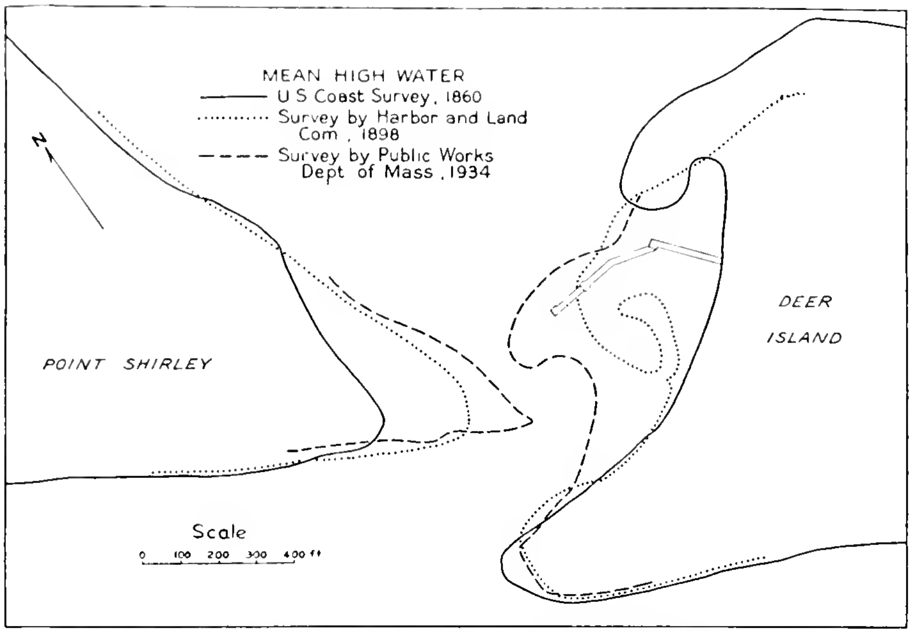
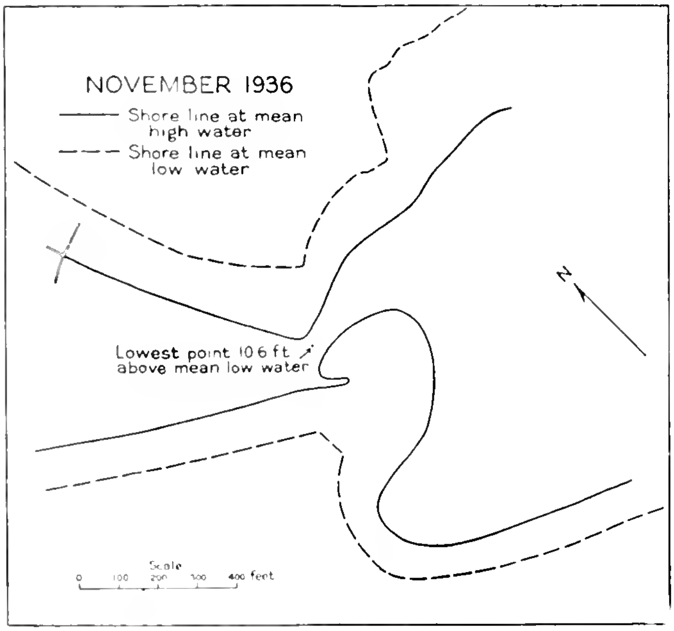


Fig. 6b.—Map of Shirley Gut in 1860, 1898, and 1934



6c. —Map of Shirley Gut in 1936. Map by R. L. Nichols and Louis Riseman

Figure 6. Diagrams showing the closing of Shirley Gut.

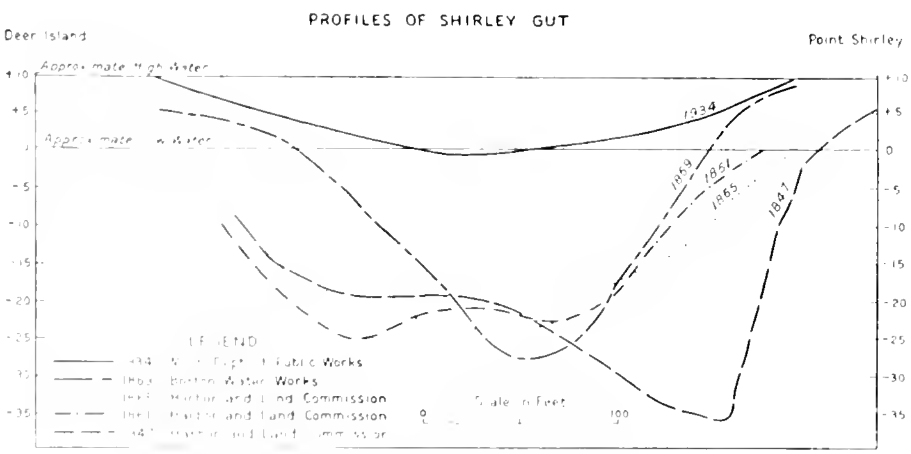
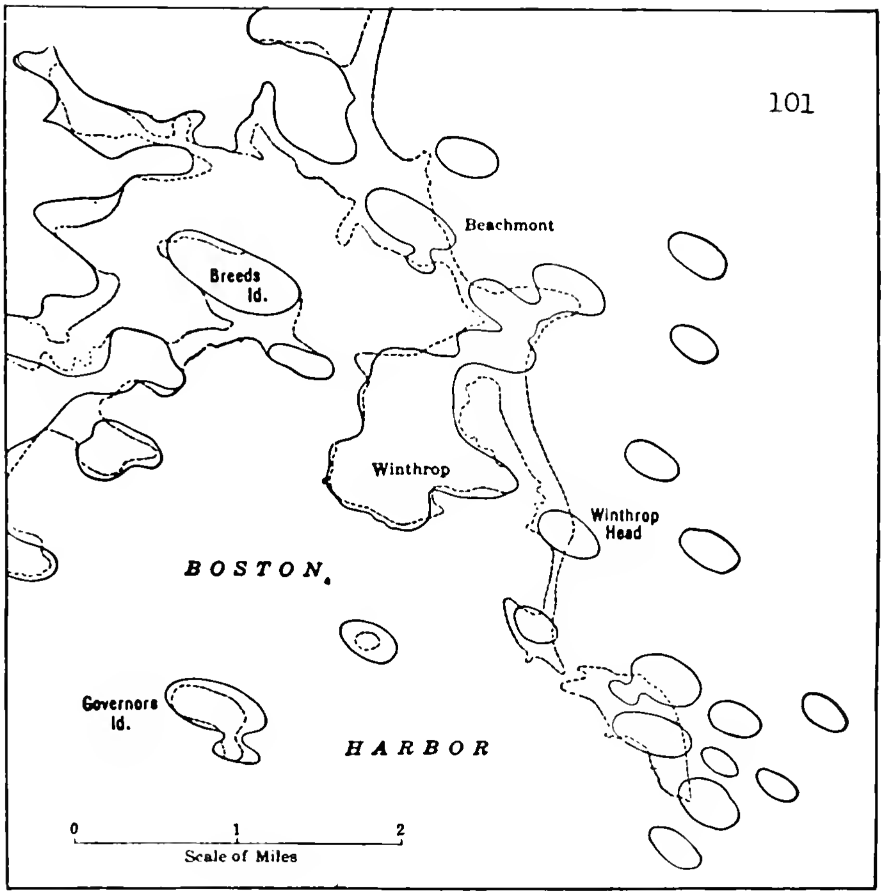


Fig 6d Transverse profiles of Shirley Gut

after Nichols



drumlins
eroded drumlins
boulder pavements
tied islands
tombolos
marine cliffs
lost islands
lost drumlins
spits
beaches
off-shore fine-grained marine deposits
shoals
wave-cut platforms

Figure 7. Restoration of initial drumlin shoreline of the Winthrop region, Boston Harbor. Broken lines show present form of shoreline. In center of map is a glacial delta plain on which the village of Winthrop is located.

after Johnson

Discussion:

(1) story of island
(2) evidence of lost islands
historic evidence
shoals
low-tide boulder-pavement islands
boulder pavements
volume of beaches
alignment of beaches
height and orientation of marine cliffs
(3) localities

Shirley Gut Drumlin Stop. Winthrop Massachusetts, Hull Quad., Massachusetts (Fig. 3 8).

The following geologic features are present:

(1) fossil marine cliff
(2) prograded beach
(3) till
(4) eolian sand
(5) beach-buried boulder pavement
(6) wave-cut platform
(7) polygenetic topography

Discussion:

(1) Why the change from a retrograding to a prograding coastline?

Short Beach Stop Winthrop, Massachusetts, Lynn Quad., Massachusetts (Figs 3 9)

The following features can be seen:

(1) Beachmont drumlin: coalescing drumlins (Winthrop Highlands)
(2) boulder pavements
(3) peat and marsh in back of beach
(4) peat on beach face
elevation
characteristics
significance
(5) retrograding beach

Winthrop Head Drumlin Stop, Winthrop Massachusetts, Hull Quad., Massachusetts (Figs. 3. 10)

The following features can be seen:

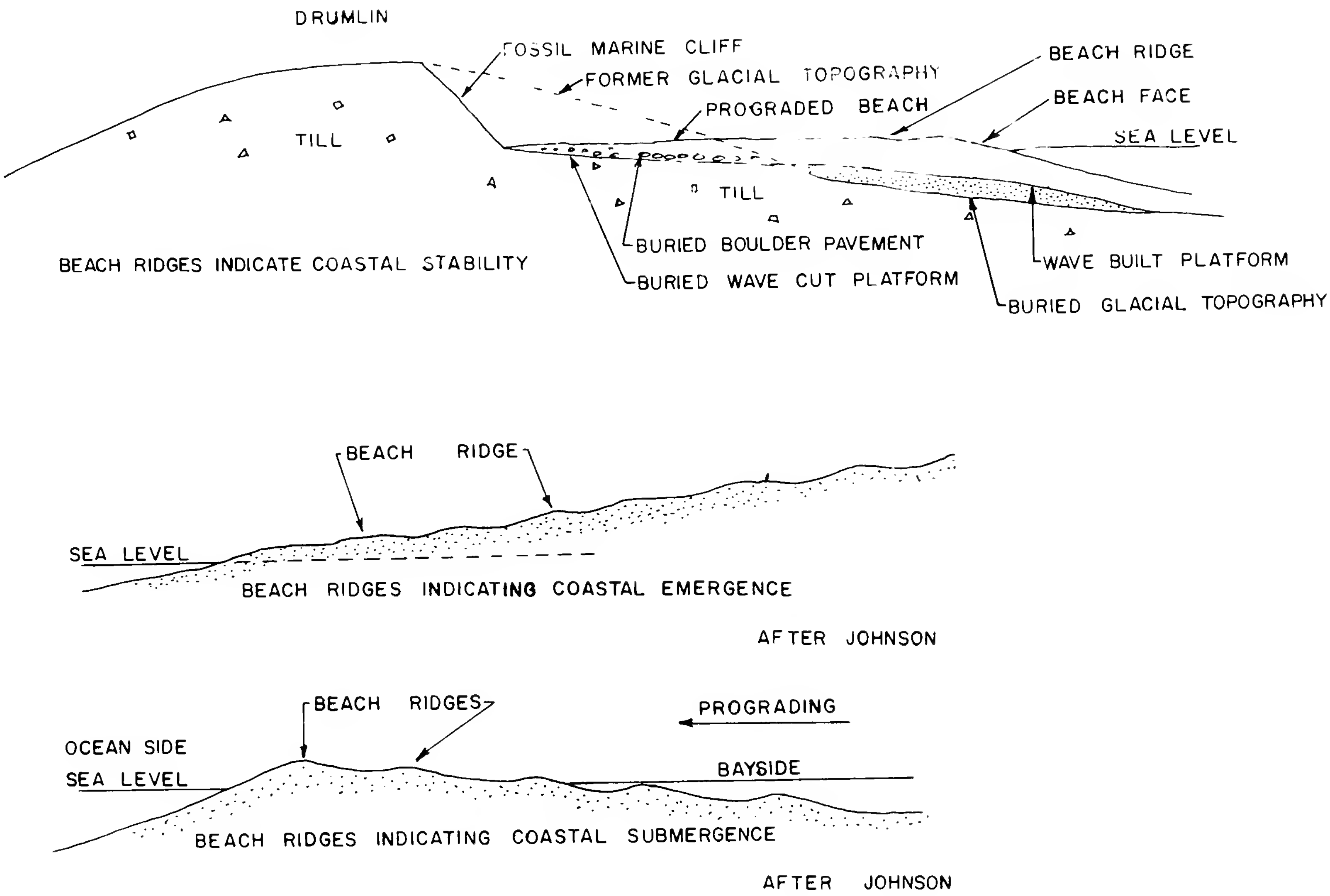


Figure 8. Beach ridges on emerging, submerging, and stable coastlines.

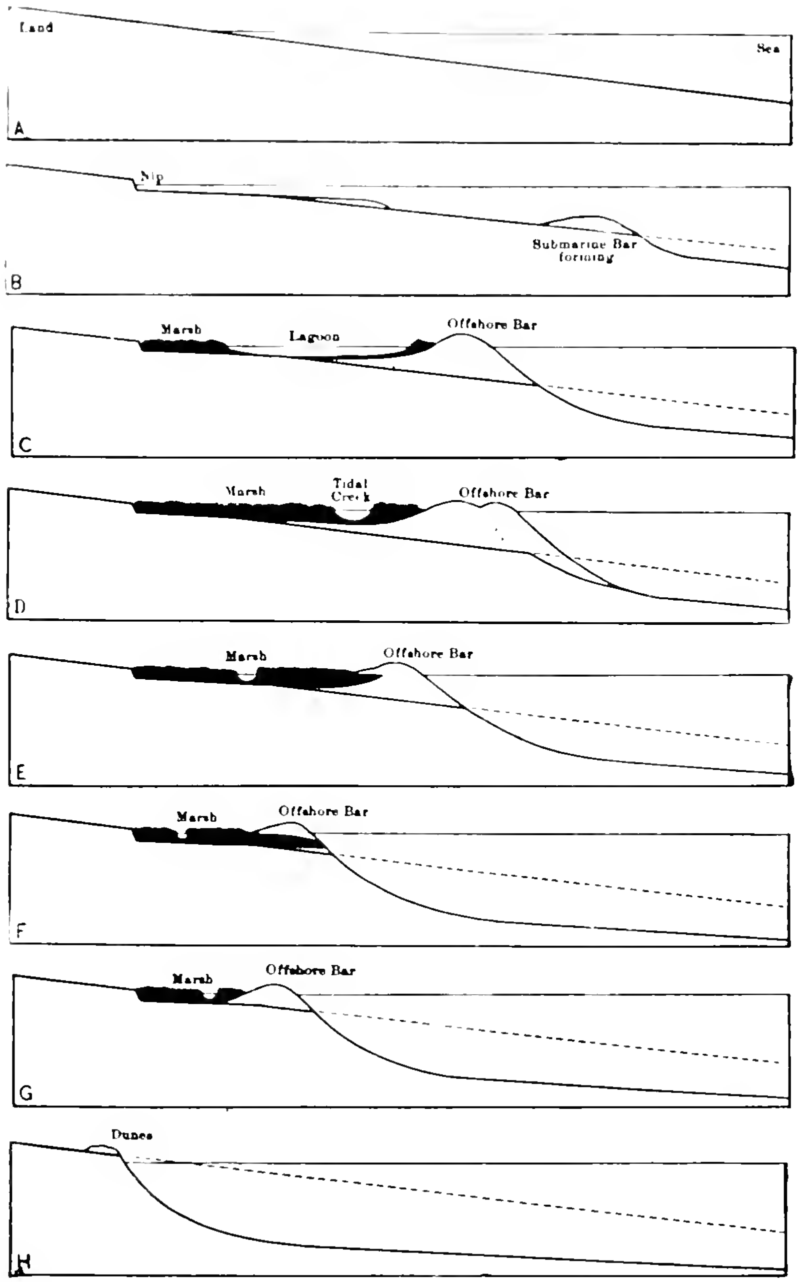


Figure 9. Stages in the normal history of an offshore bar, due account being taken of the effect of migrating inlets. Between stages F and G an inlet has migrated past the zone of the cross section, producing conditions similar to those in stage C or D.

after Johnson
Shore Processes and Shoreline Development, Wiley and Sons, Inc.

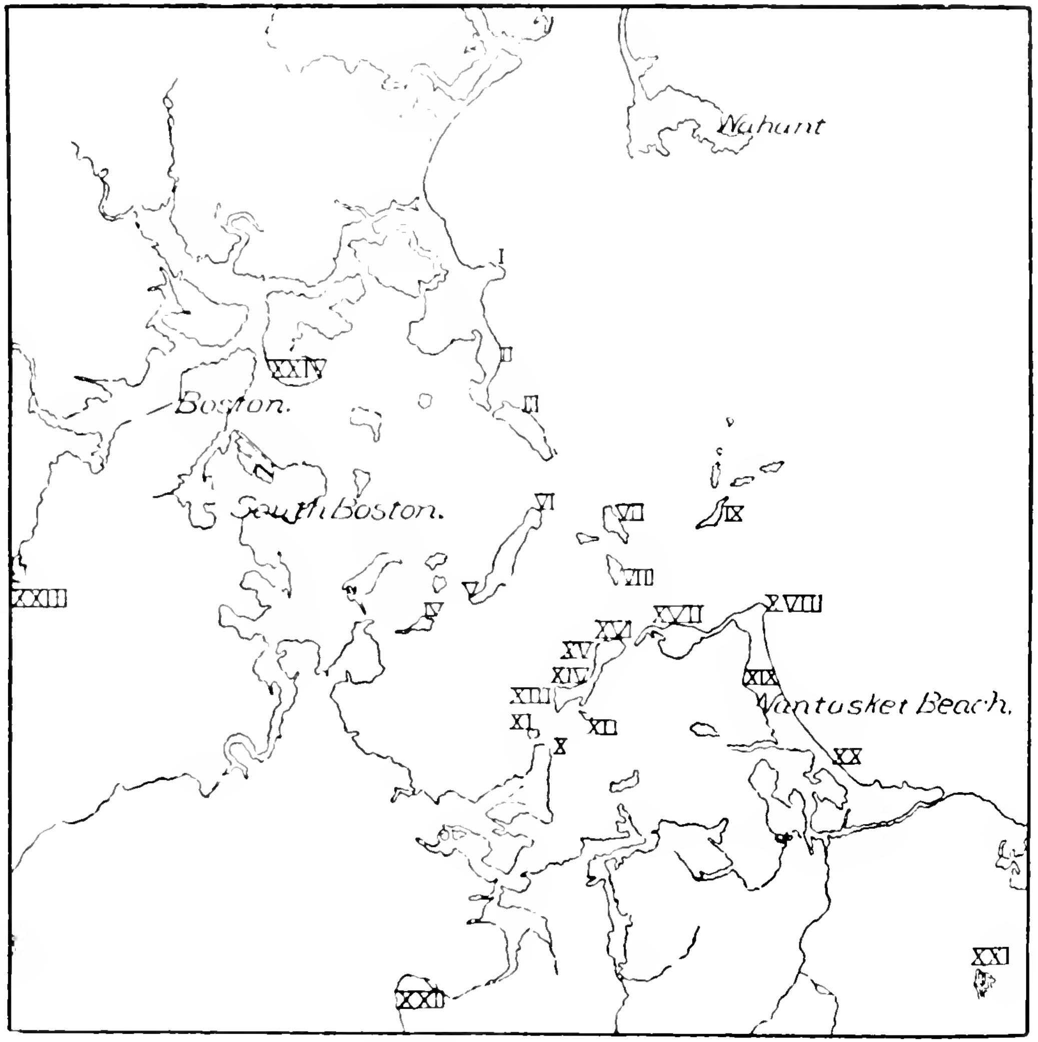
Fossiliferous till is rare in this country, although it was described many years ago from Boston and elsewhere. On the other hand, it is fairly common in England because the British glaciers deployed into marine deposits in many places.

Fossiliferous outwash plains and eskers have not been described in America. Nevertheless, such features are common in Weymouth, Massachusetts, where several eskers and outwash plains contain abundant shells. The shells are water worn; the largest fragments are nearly 3 inches long. Where the material of these eskers and sand plains is fine-grained, a shell sand is often found.

James Miller has identified the following forms, all of which are now living: (1) *Eupleura caudata*, (2) *Ostrea virginica*, (3) *Nassarius obsoleta*, (4) *Venericardia borealis*, (5) *Crepidula fornicata*, (6) *Venus mercenaria*, (7) *Nassarius trivitata*, (8) *Urosalpinx cinereus*, (9) *Anachis avara*, (10) *Polinices* sp?. This assemblage indicates warmer water than that now found in Boston Harbor.

Apparently, as the glacier moved over the inter-glacial Boston Harbor, it picked up mud and sand which contained shells. Later, these shells were either incorporated with the till or were washed out of the ice and into the eskers and outwash deposits. The presence of these marine shells in the till and fluvio-glacial deposits suggests that the strand line, usually considered as pre-Wisconsin, was not far from the present one.

by R. L. Nichols
G. Stimson Lord



Map of Boston Harbor, showing the distribution of the fossiliferous drift sections. Scale, 1 inch = 4 miles.

I, Grover's Cliff; II, Winthrop Great Head; III, Deer Island; IV, Moon Island; V, West End of Long Island; VI, Long Island Head; VII, Lovell's Island; VIII, George's Island; IX, Great Brewster Island; X, Quincy Great Hill; XI, Nut Island; XII, Princess Head; XIII, XIV, XV, XVI, Peddock's Island; XVII, Telegraph Hill, Hull; XVIII, Point Allerton, Hull; XIX, Strawberry Hill, Hull; XX, Sagamore Head, Hull; XXI, well on James' Hill, Cohasset; XXII, well in Braintree; XXIII, well in Jamaica Plain; XXIV, well in East Boston.

after Crosby and Ballard

Figure 10. Map showing distribution of fossiliferous till in Greater Boston.

(1) eroded drumlin
(2) boulder pavement
(3) beach ridge
(4) cliff profile
(5) yellow and gray till
(6) fossiliferous gray till

Subjects for Discussion.

(1) rate of recession of marine cliff
(2) duration of coastal stability from boulder pavement
(3) restoration of drumlin
(4) distribution of fossiliferous till
(5) distribution of fossiliferous outwash
(6) age and climatic significance of shells

Roughans Point Stop, Revere, Massachusetts Lynn Quad., Massachusetts
(Figs. 3, 11, 12, 13)

The following features can be seen:

(1) cuspate beach
(2) Cherry Island boulder pavement
(3) peat and marsh in back of beach
(4) distribution of marine cliffs on Beachmont drumlin
(5) peat on beach face
(6) peat pebbles, limestone veneer on angular beach fragments
(7) Boston blue clay and Boston Harbor silts off shore

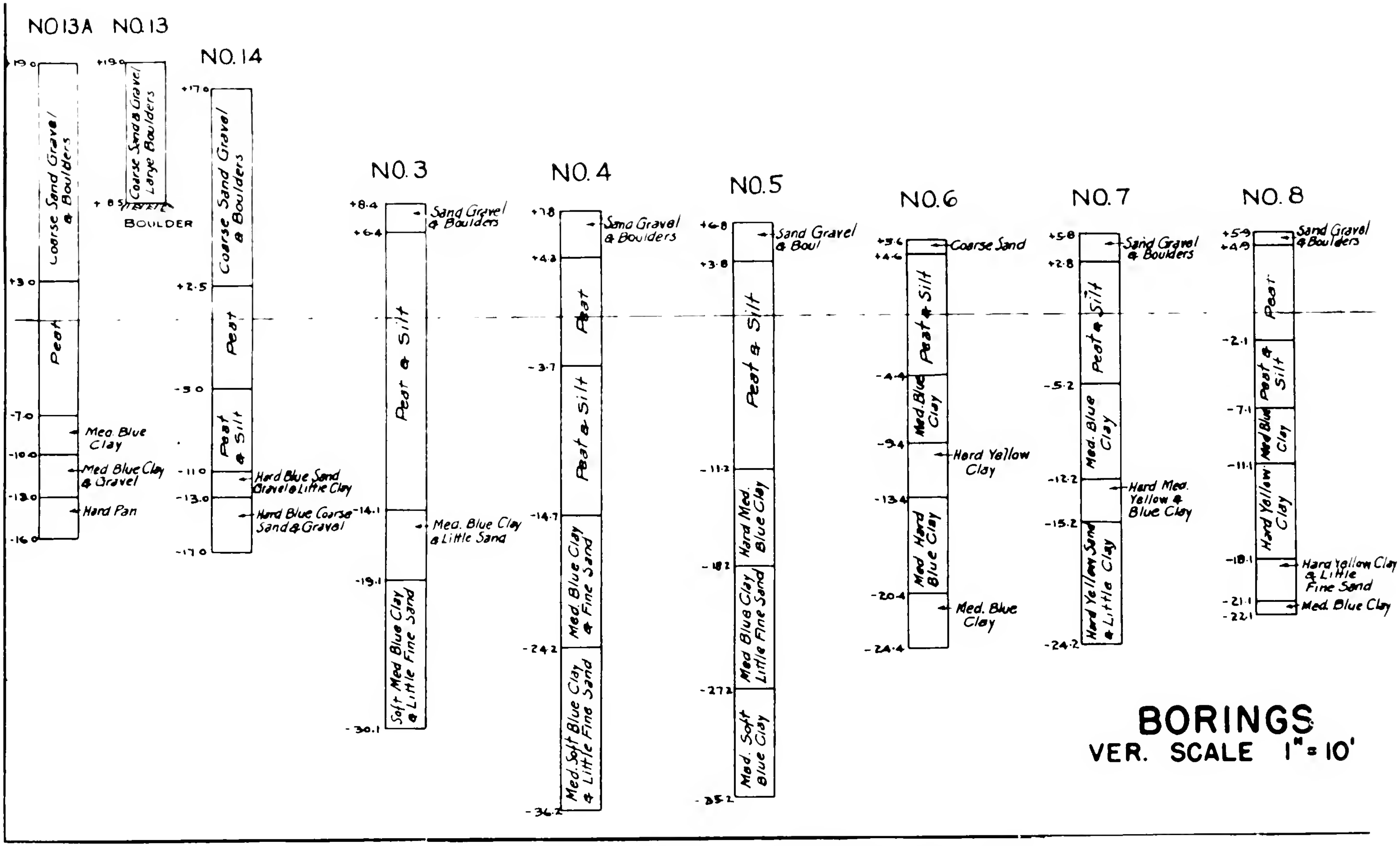
Subjects for Discussion.

(1) Cherry Island drumlin
destroyed in 18th century
size
(2) stratigraphic sections
(3) proof of retrograding beach
peat
boulder pavement
real estate
(4) significance of peat and diatoms
(5) evolution of beach

Winthrop Beach Stop, Winthrop, Massachusetts, Lynn Quad., Massachusetts
(Figs. 3, 14)

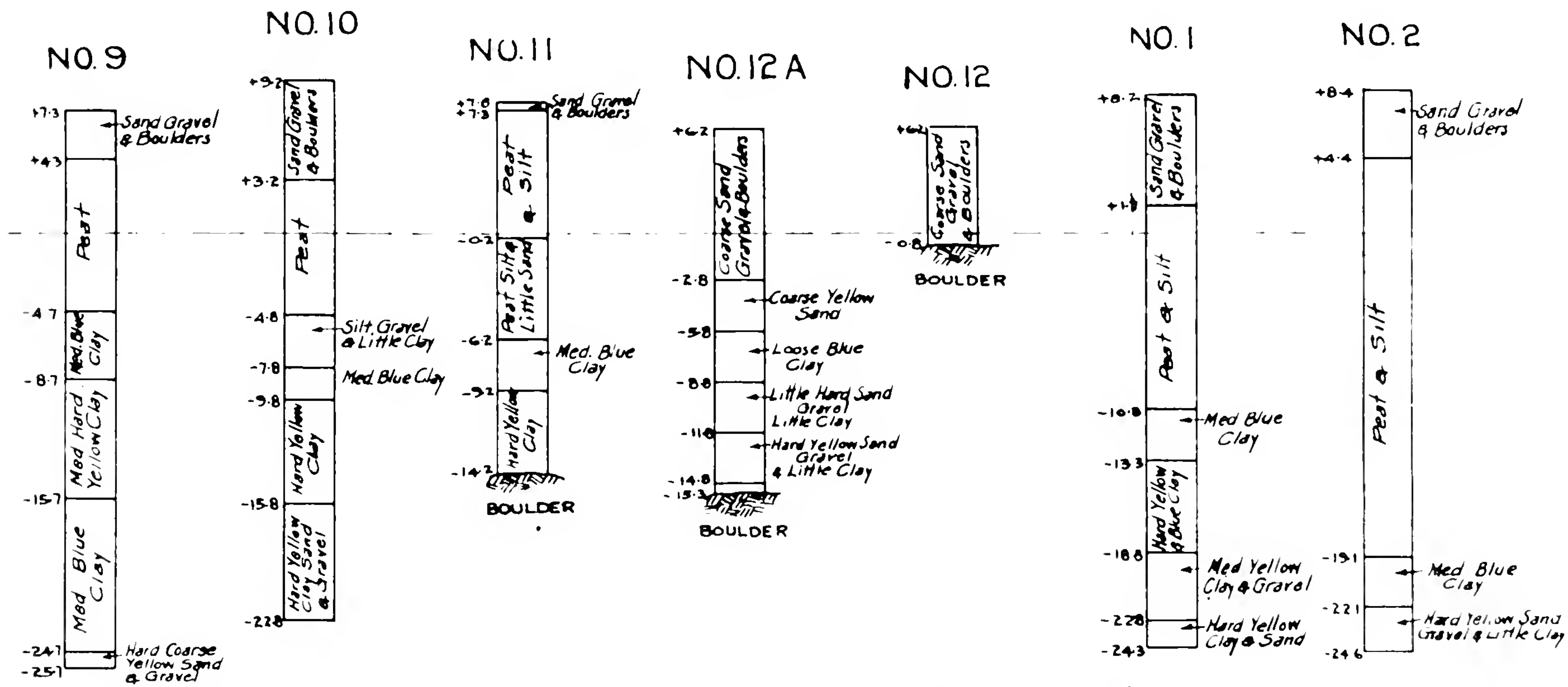
Discussion:

(1) roads perpendicular to beach slope landward
significance



Roughans Point, Beachmont, Lynn Quad., U. S. G. S.
Borings made to see what kind of foundation there
was for a sea wall.

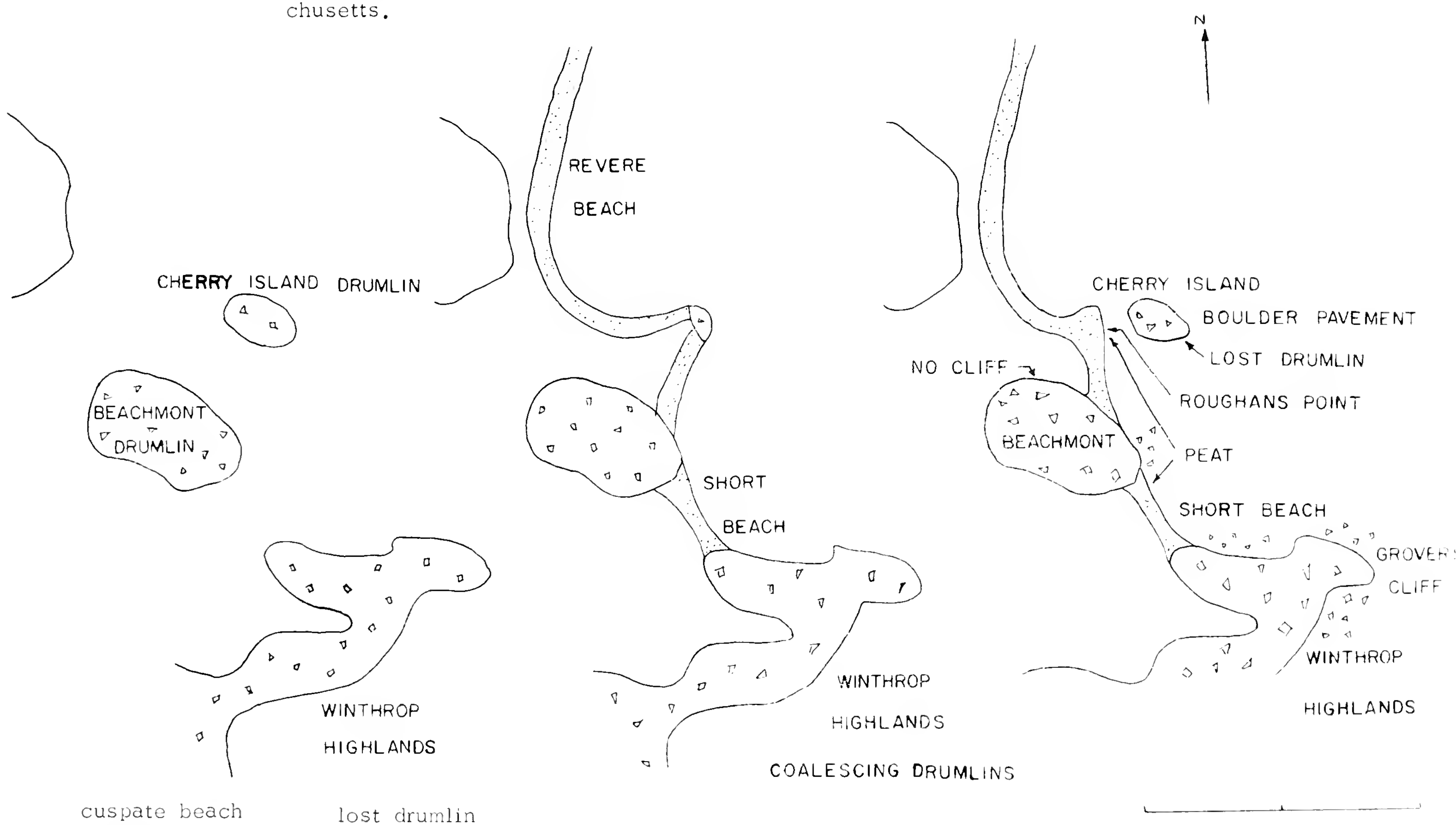
Figure 11. Columnar sections, Roughan' Point, Revere, Massachusetts.



Roughans Point, Beachmont, Lynn Quad., U. S. G. S. Borings made to see what kind of foundation there was for a sea wall.

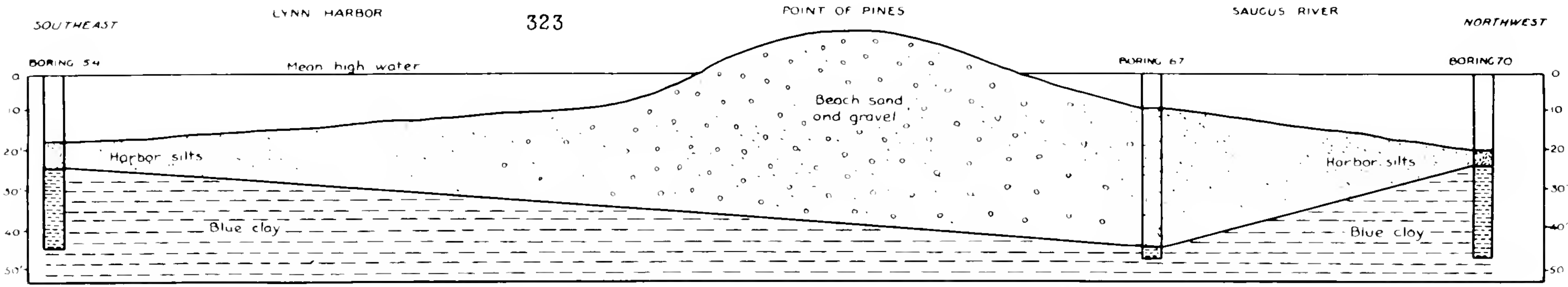
Figure 12. Columnar sections, Roughans Point, Revere, Massachusetts.

Figure 13. Diagrams showing the development of Roughans Point, Revere, Massachusetts.

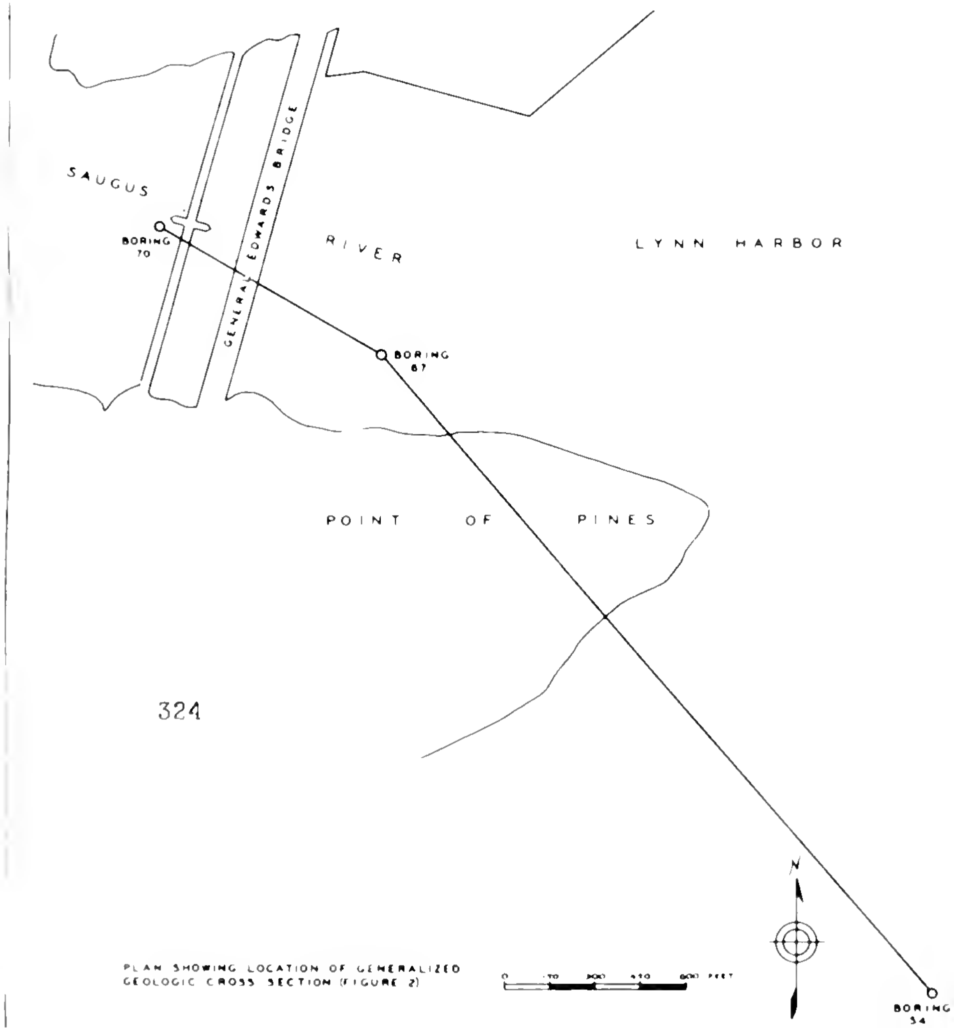


cuspate beach
drumlins
coalescing drumlins
boulder pavements
marine cliffs
lost island

lost drumlin
offshore peat
tombolo
marsh deposits
retrograded beach



GENERALIZED GEOLOGIC CROSS SECTION THROUGH POINT OF PINES, SHOWING POSITION OF BLUE CLAY.



PLAN SHOWING LOCATION OF GENERALIZED GEOLOGIC CROSS SECTION (FIGURE 2)

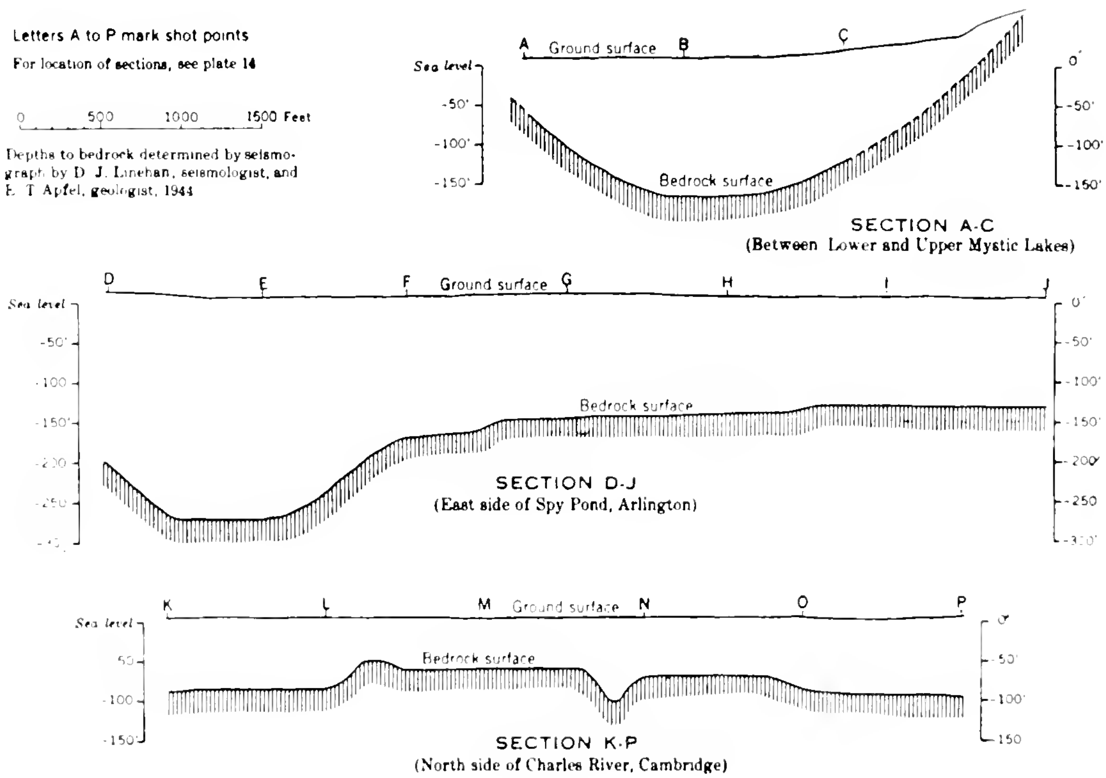
Fig. 14 valley out in Boston Blue Clay by Saugus River during low stand of sea

section not transverse to valley

(2) proof of post-glacial low stand of sea level
beach ridges
archaeological evidence
submerged weathering profiles
submerged fresh water peat
drowned forests
submerged sub-aerial valleys cut in Boston Blue
oyster line
marine peat

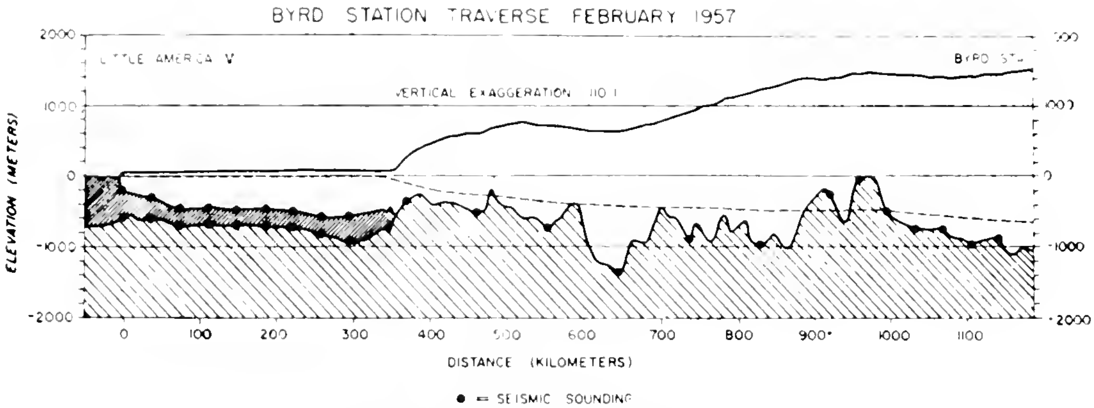
(3) breakwater (1934)
prograding shoreline

Pre-Glacial Sea Level

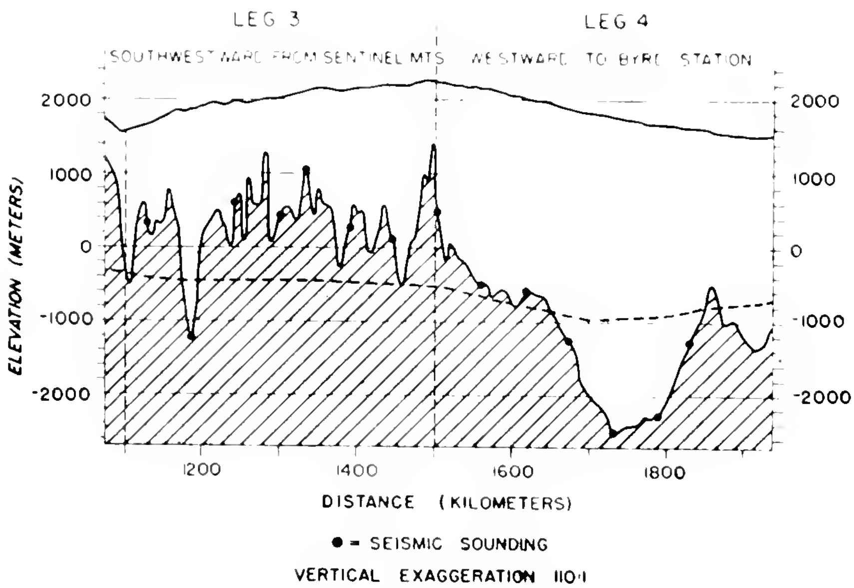


after Chute

Figure 15. The buried bedrock valleys that underlie the Mystic Lakes and the Charles River.



Profile from Little America V to Byrd Station. Dashed line represents adjusted sea-level

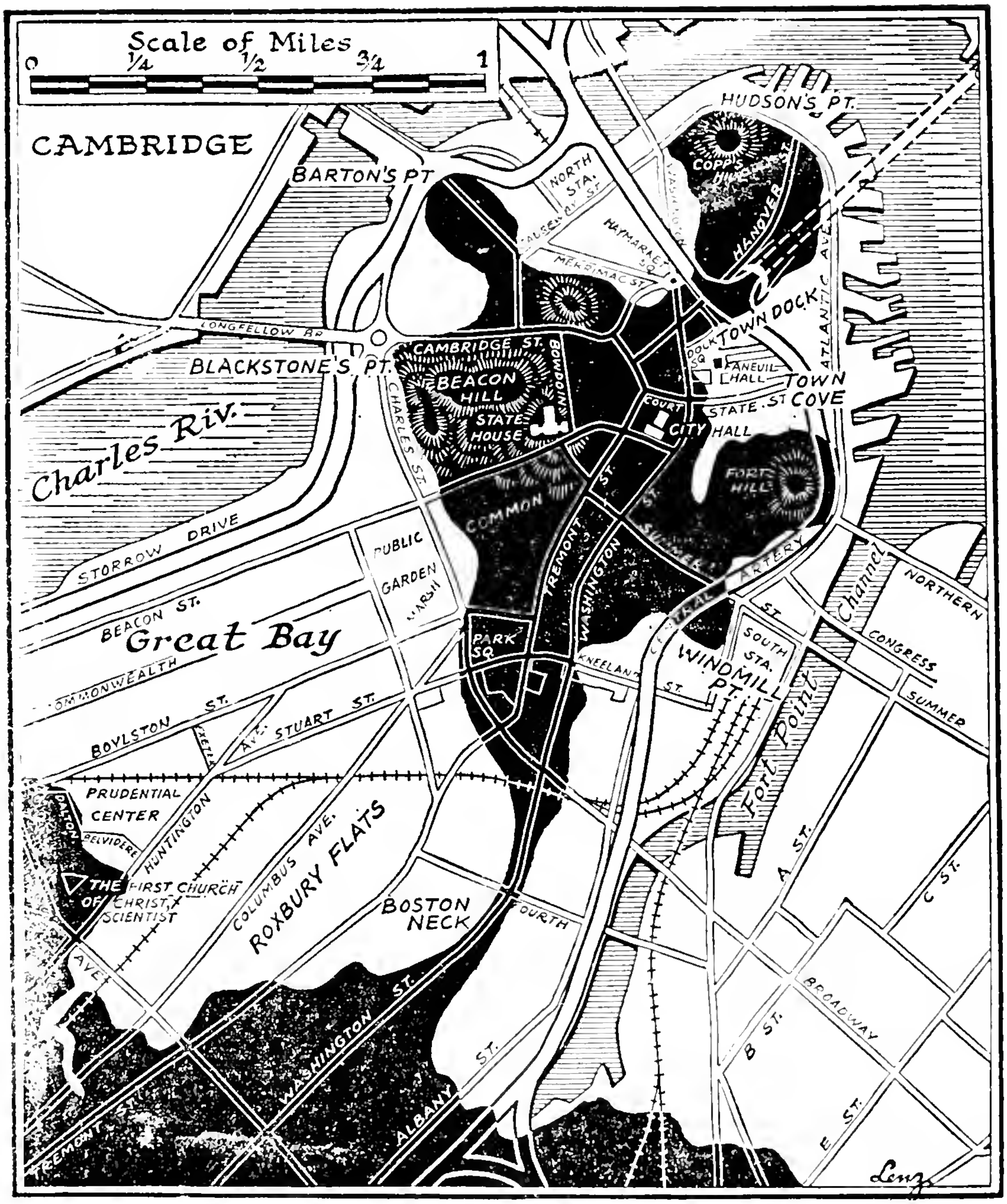


Profile along the Sentinel Mountains traverse route. Dashed line represents adjusted sea-level

after Bentley and Ostenso

Figure 16. Glacial and post-glacial sea levels in Antarctica.

Figure 17.



By Russell Lenz, Chief Cartographer

Boston: Before and After Land Fill-In Projects

Ralph Waldo Emerson's poem recalls Boston of 1773

Kenneth D. Swan, Missoula, Mont.

Q. The following poem is credited to Emerson:

> The rocky nook and hilltops three
> Looked eastward from the farms,
> And twice each day the flowing sea,
> Took Boston in its arms.

There is no question as to the references to the hilltops three, the farms, or the almost complete encirclement of Boston by salt water at high tide, but where and what was "the rocky nook?"

A. These are the opening lines of Emerson's poem "Boston," which was read in Faneuil Hall Dec. 16, 1873, on the centennial anniversary of the Boston Tea Party. In 1773, the year of which the poet was writing, Boston was still a pear-shaped peninsula jutting out into the bay, connected to the mainland by only a narrow strip of land. It seems logical to assume that this peninsula is the "rocky nook" Emerson mentioned, as one definition of "nook," now obsolete, is "a projecting piece of land." As the city grew in population and importance, land was reclaimed from the tidal overflow of the Charles River. This was done by filling in the Bay area with land taken from the "hilltops three." Beacon Hill is the only one now remaining.

courtesy Christian Science Monitor

about 4000 B. P.

about 1858

1863

Figure 19.

The Boylston Street Fishweir

by Frederick Johnson
Curator
Robert S. Peabody Foundation

THIS DIORAMA is an impression of the way the Back Bay region of Boston may have looked one early spring morning about 4,000 years ago. Indians are gathering brush to repair a fishweir in preparation for the spring run of fish. Salmon, alewives, and other migratory fish will swim along the shore at high tide, follow the brush fence, and be trapped in the heart-shaped enclosure beyond. It is low tide and one dugout canoe is being pushed off the mud to go out to the weir. Other weirs may be seen in the background.

The view across Back Bay is east toward what is now Boston Common, with Beacon Hill prominent in the background and Breed's and Bunker Hills across the Charles River in the distance. The present Charles Street would run just below the trees or about forty feet above the shore line of the Beacon Hill depicted in this diorama. The smoke rising from the Common is from Indian campsites which we believe must have been located here.

Proof of the existence of these weirs along the shores of the ancient Back Bay was discovered in 1939 when the foundations for the New England Life home office building were dug, unearthing 65,000 stakes, all of which had been sharpened by stone axes. These excavations penetrated some eighteen feet of gravel dumped to fill in the Back Bay during the 1850's and 1860's as shown in the next diorama. Beneath this fill was a twelve-foot layer of mud, which had accumulated as the level of the ocean rose over the centuries. Stakes from other weirs have been uncovered while digging several foundations in the area between Boylston and Stuart Streets.

The fact that the fishweir stakes were buried in mud and that the mud included remains of plants, shellfish, and even pollen and other miscroscopic organisms was evidence that the stakes had been in place for a long time. It also confirmed the fact that sea level had risen some twelve feet during this time.

Evidence secured by scientists during this excavation was the basis of an extended research project under the auspices of the R. S. Peabody Foundation, Phillips Academy, Andover, Massachusetts, the findings of which were published in two books. The date 2500 B. C. established in this research was confirmed by radiocarbon analysis of the wooden stakes from the weir.

In these early days, a wide tidal stream ran under what is now Clarendon Street toward the ancient Charles River. In the vicinity of Beacon Street, this stream divided to flow around a long, narrow island which extended from Arlington Street to Dartmouth Street. This island partially restricted the rise and fall of the tide so that the early Back Bay was a great, shallow pond bordered by sedge meadows. There were probably islands in this pond about which the currents flowed, providing extensive spawning grounds for fish.

In addition to the fish population, Back Bay was an excellent habitat for ducks, geese, and other kinds of birds as well as deer and small game. This plentiful supply of food made it a fine place for the Indians to build their villages.

We have no way of describing these Indians in detail, but we do know that about 2500 B.C. they were living all over New England by hunting, fishing, and gathering berries and nuts. In spite of the fact that they had not learned to cultivate corn or even to make clay pottery, they were comfortable and well-fed — as the man dozing against the tree will testify!

courtesy New England Mutual Life Insurance Co.

igure 20.

The Filling-in of Back Bay

by Walter Muir Whitehill
Director and Librarian
Boston Athenaeum

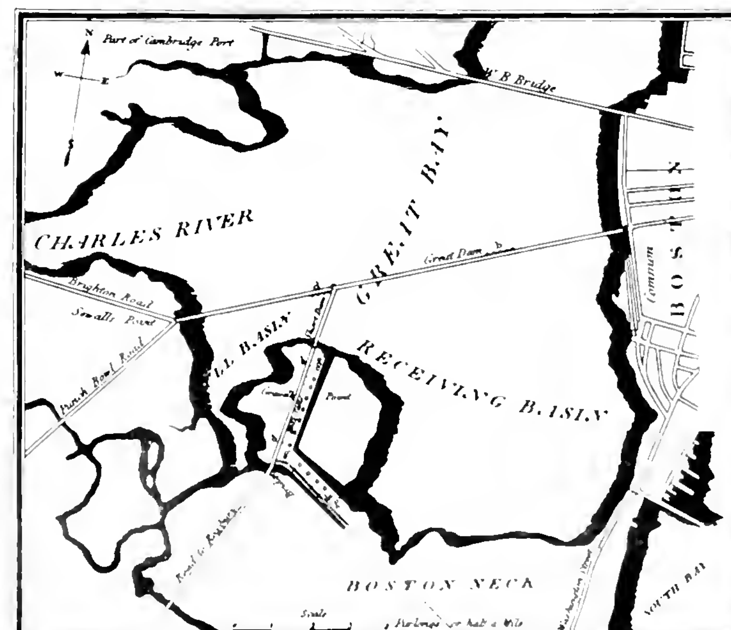
THIS DIORAMA shows the method by which the Back Bay was changed from water into land. Until the nineteenth century this name was applied to the great reaches of mud flats and salt marshes. These were covered by the water at high tide. They extended from the Charles River to the narrow neck of land that connected the peninsula upon which Boston was built with the Roxbury mainland. For it must be remembered that Boston, which now appears to be built upon a solid segment of Massachusetts coast, was originally on a hilly peninsula, almost completely surrounded by water. From the end of the eighteenth century the hills were gradually leveled or reduced in height, one by one, to fill in the coves and produce more land for an expanding town. But the greatest change in the shape of Boston began soon after the war of 1812 when Uriah Cotting undertook to dam the waters of the Back Bay to obtain tidal power for a series of mills.

A milldam, fifty feet wide and a mile and a half long, carrying a toll road, which ran along the line of Beacon Street from Charles Street to Sewell's Point (now Kenmore Square), enclosing about six hundred acres of the Back Bay, was completed in 1821. A cross dam running out from Gravelly Point in Roxbury on a line roughly corresponding to the present Massachusetts Avenue, subdivided this area into a westerly full basin and an easterly receiving basin. At high tide, water was admitted to the full basin by filling sluices just west of the cross dam; it then passed through sluices below the mill sites on Gravelly Point into the easterly receiving basin, from which it drained back into the Charles River by emptying sluices in the main dam at about the present level of Exeter Street. But before this scheme was fully developed, railway lines from Providence and Worcester which were built through the Back Bay basins seriously jeopardized Uriah Cotting's vision of industrial water power. These rights of way hampered the flowing of water, and eventually turned the Back Bay into a stinking nuisance. Thus during the eighteen fifties plans were developed for filling the entire Back Bay and creating new land.

The Legislature in May of 1857 authorized Commissioners on the Back Bay to fill in the area and sell the lands thus created. The plan adopted envisioned four new streets — Marlborough Street, Commonwealth Avenue, Newbury and Boylston Streets — parallel to the milldam, intersected at regular intervals by cross streets, alphabetically named from Arlington to Hereford. In July, 1858, the Commissioners contracted with a Vermonter, Norman Carmine Munson, to do the work. Munson and his partner, George Goss, made full use of the latest technological developments. Gravel was dug by steam shovel in Needham, nine miles away, and brought by gravel trains of thirty five cars each that ran day and night over railway tracks into the Back Bay.

The diorama shows the scene soon after work began, looking from the site of this building toward the Public Garden, Common, and Beacon Hill. Two gravel trains have reached the end of temporary spurs leading from the Boston and Providence line; are dumping their loads and are about to return to the Needham pits for more. Workmen are leveling the fill, while engineers consult plans, and forward-looking visitors contemplate the site of a future house. Before long the inexorable gravel trains, arriving every forty-five minutes, will have filled the mud flats that still appear in the diorama, and the construction of buildings along Arlington Street will begin.

Two dams divided the Back Bay basin in 1821, thereby opening a toll road along the line of the present Beacon St. and mill sites on Gravelly Point.



Map reprinted from "Boston, A Topographical History," by Walter Muir Whitehill, Harvard University Press, reproduced with permission

courtesy New England Mutual Life Insurance Co.

Figure 21.

The Boston Society of Natural History

by Walter Muir Whitehill

A LITTLE OVER five years have passed since the period represented by the preceding diorama There we were standing on the site of this building looking towards Beacon Hill. Here, in 1863, we are instead in the now-filled Boylston Street looking west towards this site.

The tone of the Back Bay was early set by the number and character of the churches and institutions that flocked there Almost on the wheels of the gravel cars came the Unitarians of the Federal Street Church, over which William Ellery Channing had presided from 1803 to 1842. This congregation began to build in 1859, at the corner of Arlington and Boylston Streets, the present Arlington Street Church

The Legislature in the winter of 1860-1861 voted to the Boston Society of Natural History, organized in 1830, a grant of land on Berkeley Street extending from Boylston to Newbury Upon this site the Society soon built a three-story brick museum, designed by William G. Preston, which is the most conspicuous feature of this diorama. Since the metamorphosis of the Society into the Museum of Science, now located in Science Park on the Charles River Basin, this handsome building has been converted into a store for Bonwit Teller's.

The remainder of the block was granted by the Legislature to the Massachusetts Institute of Technology, which had been incorporated by an act of 10 April 1861, and whose first building was authorized in 1863. That building, designed by Preston, in singularly felicitous relation to its neighbor, was named in honor of William Barton Rogers, the founder of the Institute. The diorama shows only the foundations of the Rogers Building, which was some seven decades later demolished to make way for the New England Mutual Life Insurance Company building.

The majority of the earlier Back Bay houses were built by individual owners, according to their own plans. Only in Newbury Street and the upper reaches of Marlborough was there extensive speculative construction for resale. While not by any means identical in design, or even in height, the houses in the new streets had a certain grandiose unity of feeling that set a tone for the new region. For several decades Back Bay streets had a prairie-like quality that is evident in this diorama Handsome and sophisticated buildings loom up out of a plain of dusty gravel that would, with the passage of years, be steadily reduced by new construction. But in 1864 the great open spaces predominated

In this diorama, houses on Commonwealth Avenue are built from Arlington to Berkeley Streets. On the water side of Beacon Street they extend above Clarendon, but filling is still going on, for below Dartmouth Street a gravel train is arriving with its load. The future site of Copley Square still remains to be filled

<u>Back Bay Stop,</u> Boston, Massachusetts,
Boston South Quad., Massachusetts
(Figs. 17, 18, 19, 20, 21)

Discussion:

(1) Boylston Street fish weir, sea level lower than today, (about 4000 B.P.)
(2) Milldam, cross dam, full basin, receiving basin (about 1821)
(3) Filling-in of Back Bay, Needham, Mass. sand and gravel (1859)
(4) First buildings (about 1863)

MAPS

U.S. Dept. Interior, Geological Survey, Boston South Quad., Massachusetts

U.S. Dept. Interior, Geological Survey, Hull Quad., Massachusetts

U.S. Dept. Interior, Geological Survey, Lynn Quad., Massachusetts

U.S. Dept. Interior, Geological Survey, Newton Quad., Massachusetts

TRIP A - Saturday

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NORTHEASTERN MASSACHUSETTS GEOMORPHOLOGY- Sunday, Trip A

Robert L. Nichols, Tufts University

Patch Beach Stop, Beverly, Massachusetts, Marblehead North Quad., Massachusetts (Fig. 1).

Features to be seen:

(1) uplifted marine clay
(2) marine cliff
(3) retrograding baymouth beach
(4) valley cut in clay
(5) magnetiferous and pyritic sands
(6) man-made fill

Discussion:

(1) Colonial trail
(2) city land grab
(3) magnitude of marine erosion since Colonial time
(4) reason for location of valley

Rafe's Chasm Stop, Normans Woe, Magnolia, Massachusetts, Gloucester Quad., Massachusetts (Fig. 2).

Magnificent examples of marine chasms eroded along trap dikes and shear planes (you have never seen any as good).

Geologic features to be seen:

(1) dike chasms
(2) shear plane chasms
(3) wave-cut bench
(4) wave-washed surfaces
(5) boulder beach
(6) single, compound, and composite dikes, screens
(7) .phenocrysts and inclusions in dikes
(8) Quincy Granite

Discussion:

(1) glacial erosion along dikes
(2) positions of sea level
(3) origin of bedrock cliffs

Topsfield Road Stop, Ipswich, Massachusetts (1.8 miles from Ipswich Post Office going southwest along Topsfield Rd.).

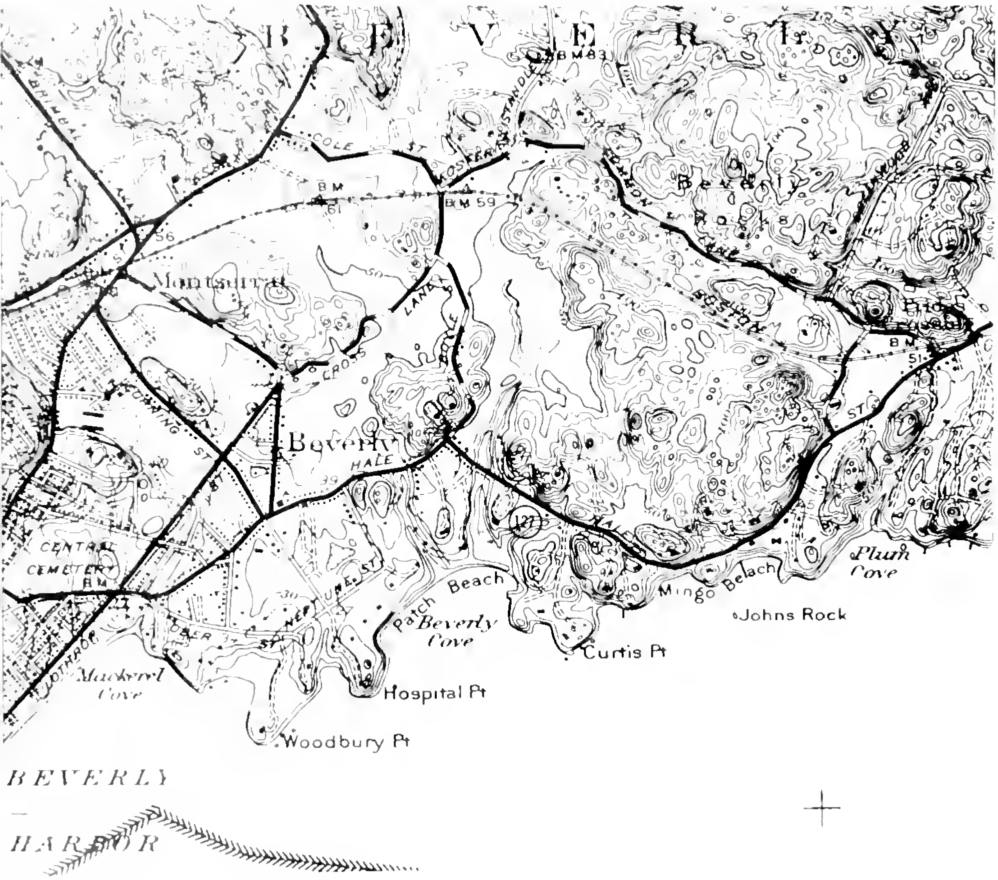
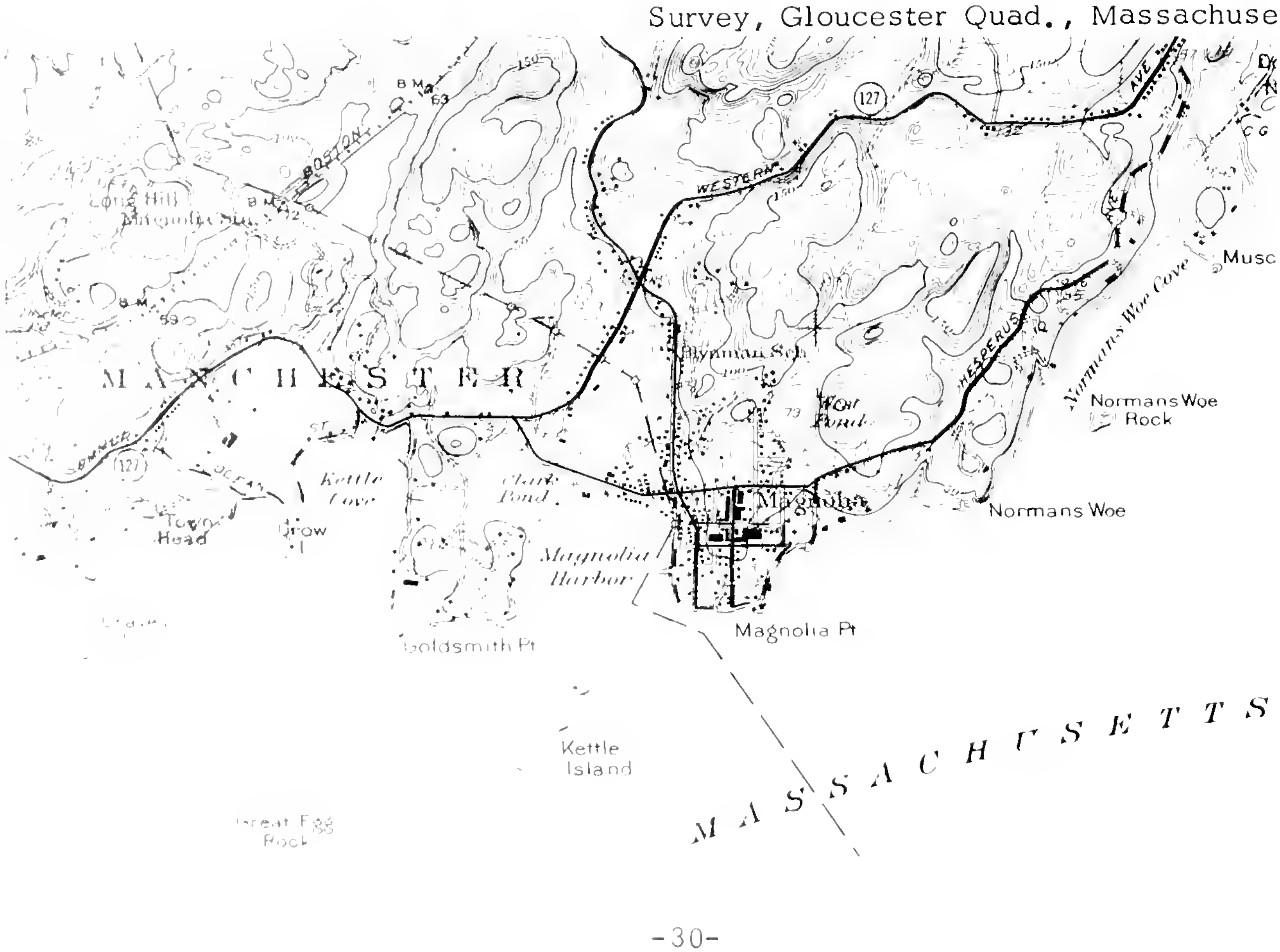
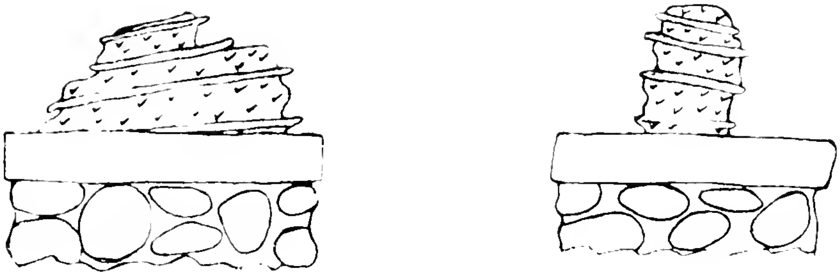


Figure 1. Part of U.S. Dept. Interior, Geological Survey, Marblehead North Quadrangle, Massachusetts.

Figure 2. Part of U.S. Dept. Interior, Geological Survey, Gloucester Quad., Massachusetts.

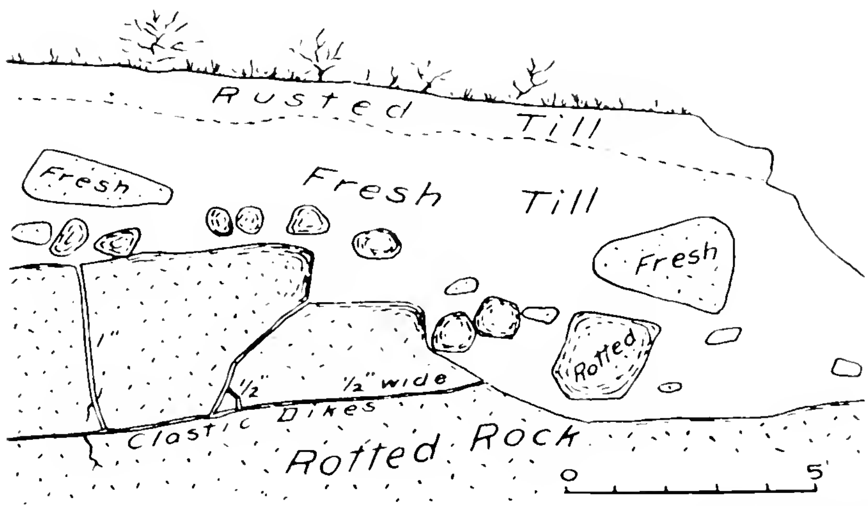




Topsfield Rd., Ipswich

Mushroom Rocks
side view
front view
igneous rock
resistant layers
cement cap of fence post
significance?
$1\frac{1}{2}$ feet long
differential erosion
differential weathering
Wisconsin till source?

a



after Goldthwait
and Kruger

pre-glacial weathering
post-glacial weathering
weathered fragments
unweathered fragments

proof?

b

Figure 3. a. Oddly shaped boulders, Topsfield Road, Ipswich, Massachusetts
b. Pre-glacial weathering.

Discussion:

(1) significance of oddly shaped boulders
(2) pre-glacial weathering

<u>North End of Plum Island Stop</u>, Newburyport, Massachusetts, Newburyport East Quad., Massachusetts (Figs. 4, 5, and 6).

Plum Island is a barrier beach between 7 and 8 miles long and in most places between ½ and 1 mile wide. It is composed mainly of beach sands and gravels, dune sand, and marsh deposits, although on its southern end there are small areas of till, outwash, and marine clay. Salisbury beach, which is north of Plum Island, is also a barrier beach about $4\frac{1}{2}$ miles long composed of beach sands and gravels, dune sand, and marsh deposits. The Merrimack River reaches the ocean between Plum Island and Salisbury beach.

The northern end of Plum Island is forked. The eastern prong is approximately $1\frac{1}{4}$ miles long and at its widest point ½ mile wide. Between the eastern and western prongs is a shallow body of water called the Basin.

A study of maps made in 1942 by the U.S. Army Engineers showed that the eastern prong had been formed in the last [illegible] years.

In 1827 the northern end of Plum Island was not forked. Between 1827 and 1851 the eastern side retrograded about half a mile southward. The western side was modified later to form the western prong. Following this period of retrograding southward, a spit, attached to the eastern side, prograded northward so that by 1851 it was more than a mile long. Since 1851 this spit, the eastern prong, has greatly increased in size. In 1942 it had an area of approximately .3 sq. mile.

<u>North Ridge Stop</u>, Ipswich, Massachusetts, Ipswich Quad., Massachusetts.

<u>Dune-Veneered Spit West of Steep Hill Stop</u>, Ipswich, Massachusetts, Ipswich Quad., Massachusetts (Fig. 7).

<u>Castle Neck Stop</u>, Ipswich, Massachusetts, Ipswich Quad., Massachusetts (Fig. 7).

Geologic features which can be seen are:

(1) dune-veneered drumlin
(2) dune-veneered [illegible]
(3) dune-veneered [illegible] spit
(4) second-story boulder pavement
(5) periglacial ventifacts
(6) cross-bedding, [illegible]outs, eolian depressions, garnetiferous sand, etc.

Figure 4. Index map showing Plum Island, Salisbury Beach, and the Merrimack River.

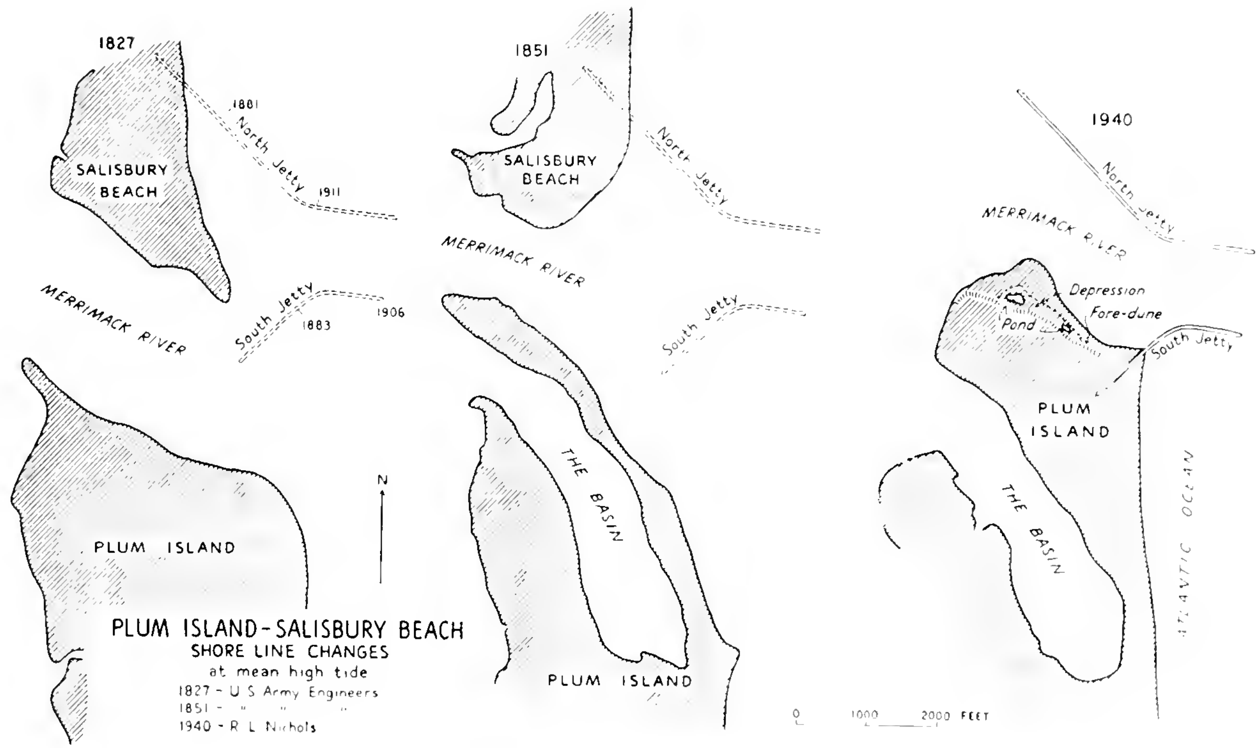


Figure 5. The positions of the north end of Plum Island in 1827, 1851, and 1940.

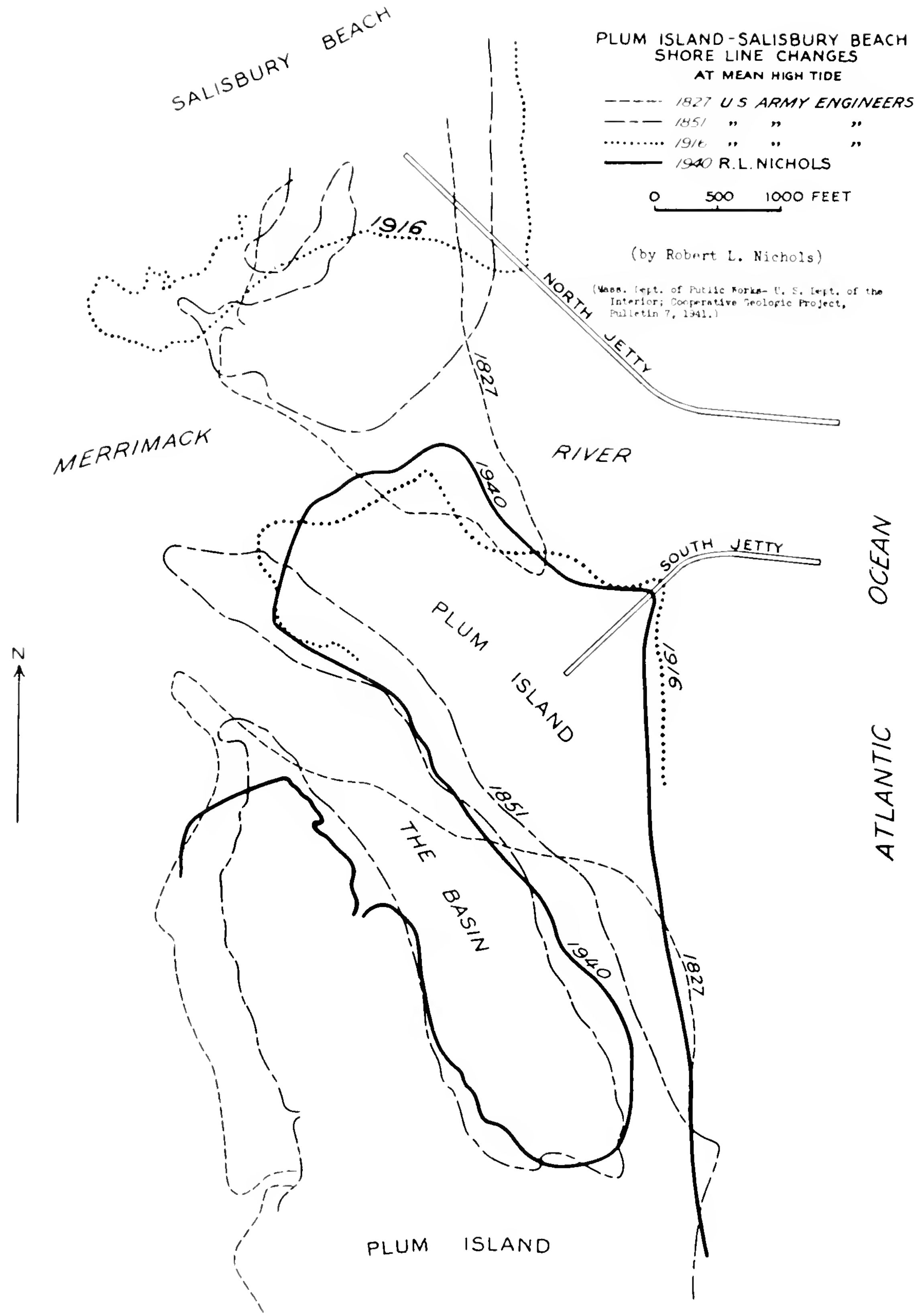
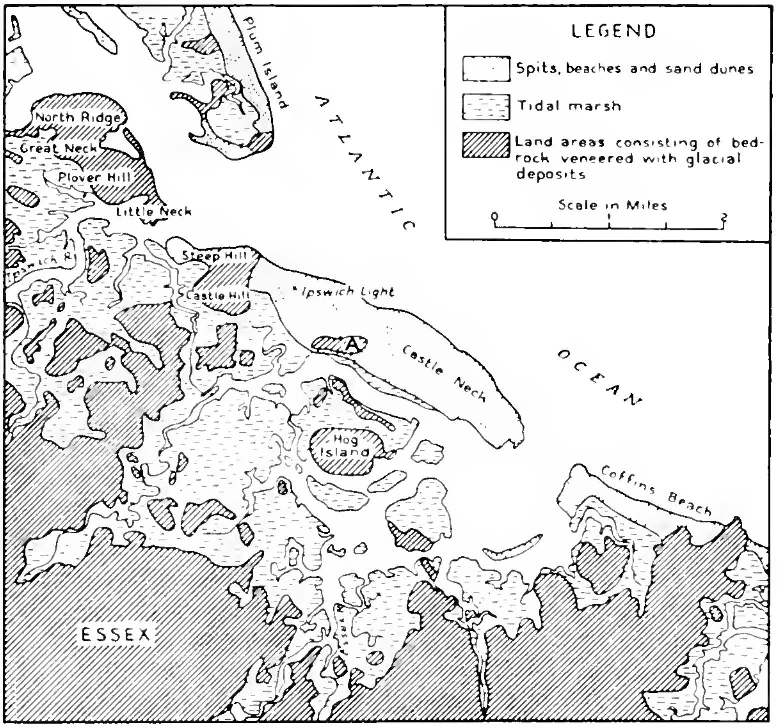


Figure 6. Map showing successive positions of the northern end of Plum Island, and the southern end of Salisbury Beach from 1827 to 1940.

North Ridge Stop, Ipswich, Massachusetts, Ipswich Quad., Massachusetts.



North Ridge
drumlin
till
clay-till contact
elevated marine clay
weathered till below clay
multiple glaciation?
clay pebbles on beach
wave-out platform
on till
on clay
marine cliff
elevated marine cliff?
elevated wave-cut platform?
elevated boulder pavement?
patches of loess in road cuts
few feet thick
weathered loess

Figure 7. A map showing North Ridge, Castle Neck, and the dune-veneered spit west of Steep Hill, Ipswich, Massachusetts.

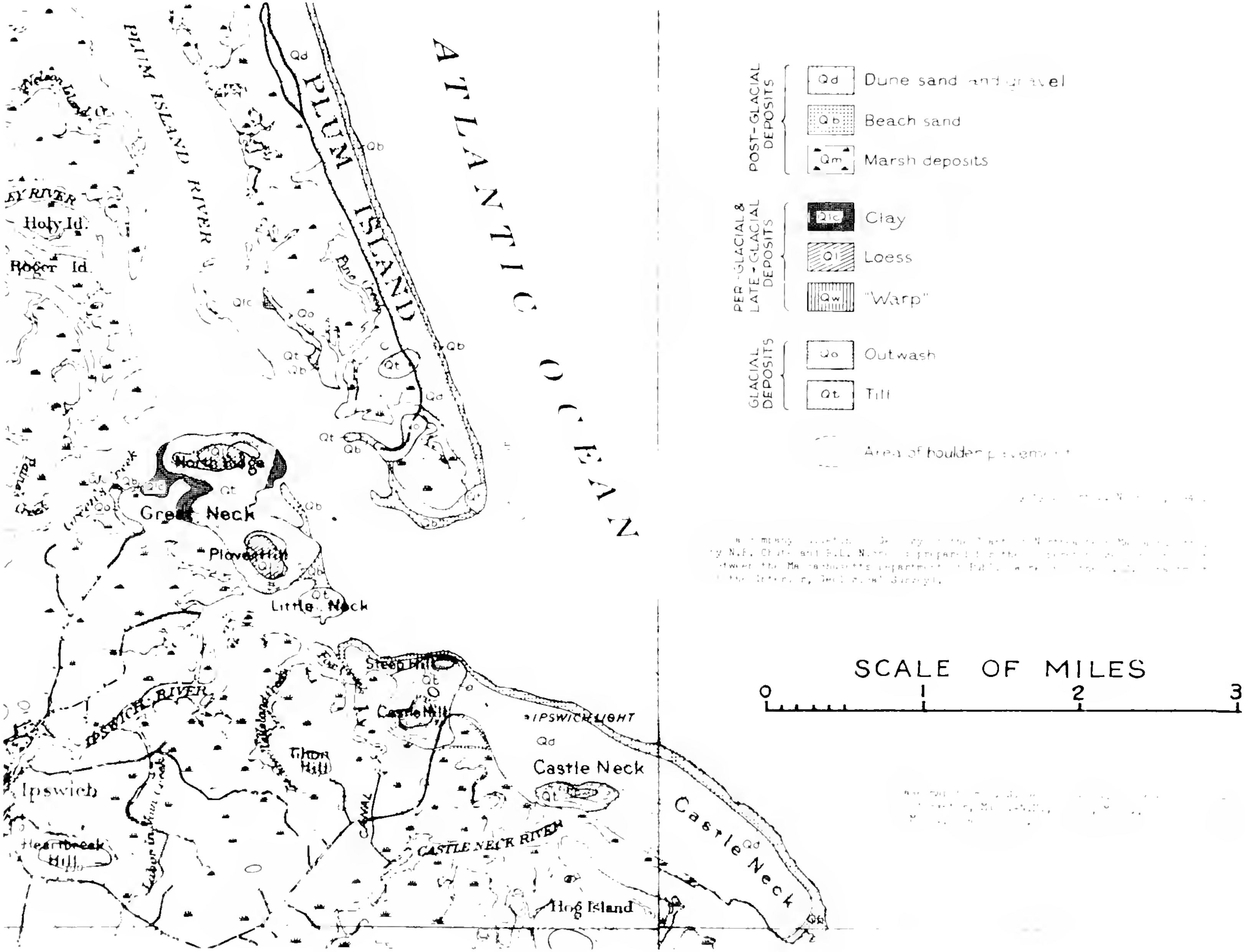
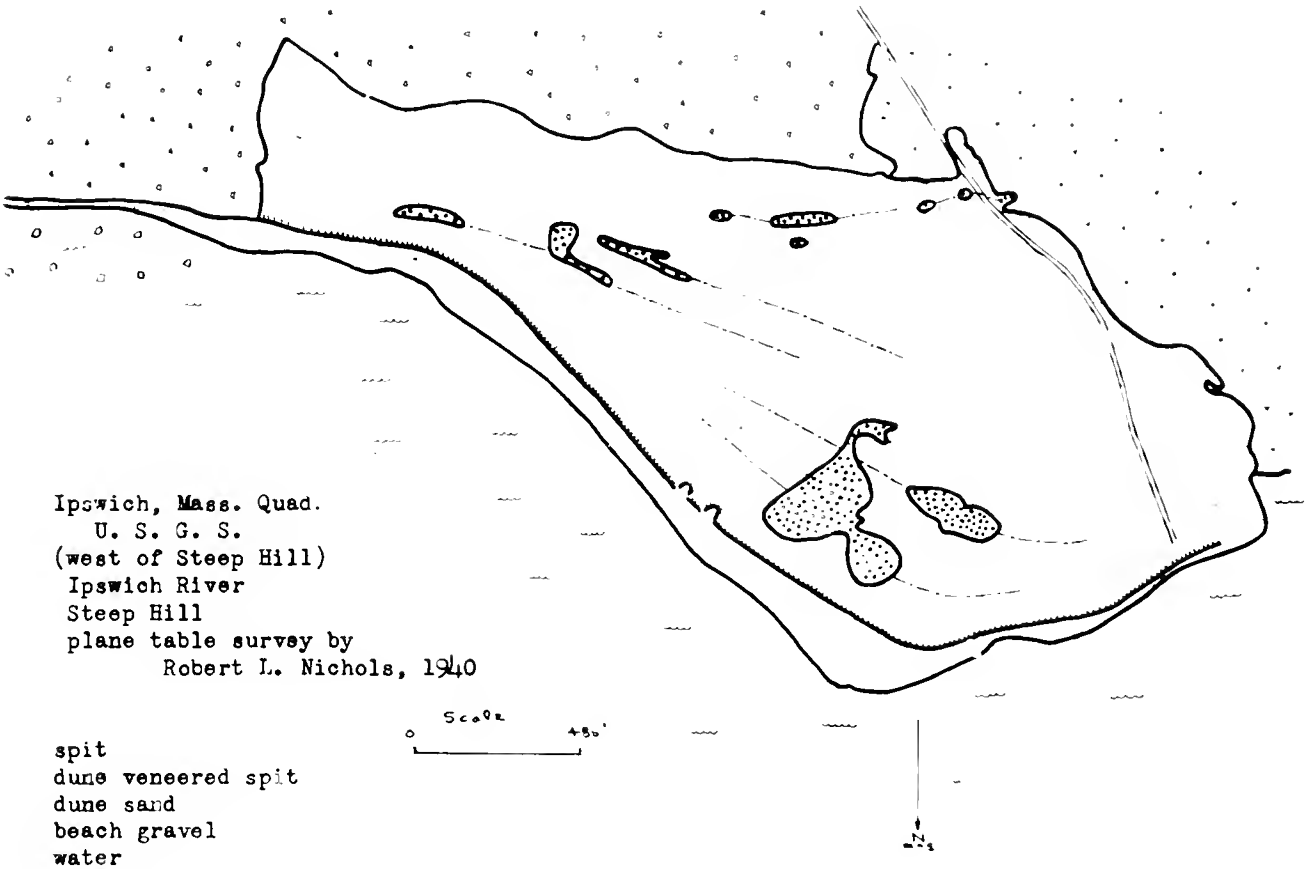
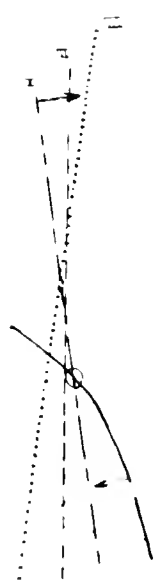


Figure 8. Geologic map of the south end of Plum Island, the Great Neck area, and the Castle Neck area, Ipswich Quad., Massachusetts.

Dune-Veneered Spit West of Steep Hill Stop, Ipswich, Massachusetts, Ipswich Quad., Massachusetts.



spit
dune veneered spit
dune sand
beach gravel
water
marsh
till
drumlin
inactive marine cliff
boulder pavement
wave-cut platform
blow outs
parabolic dunes
dune veneered till
dune veneered drumlin
dune buried soil on drumlin
beach veneered boulder pavement
ripple marks
eolian cross bedding
sand slides
grass rings
sand domes
beach ridges
dune migration
dune buried trees
ripple mark migration
yardangs
garnetiferous sand
boundary of drumlin and beach
boundary of drumlin and dunes
boundary of dunes and beach



spit I
spit II
spit III
land
ocean
wave cut platform
beach deposits
retrograding cliff
retrograding beach
fulcrum I
fulcrum II
fulcrum III
shifting fulcrum
initial shoreline
marine cliff I, II, III.

garnet history
bedrock → till → beach → dunes

Figure 9. Dune-veneered spit immediately west of Steep Hill, Ipswich.

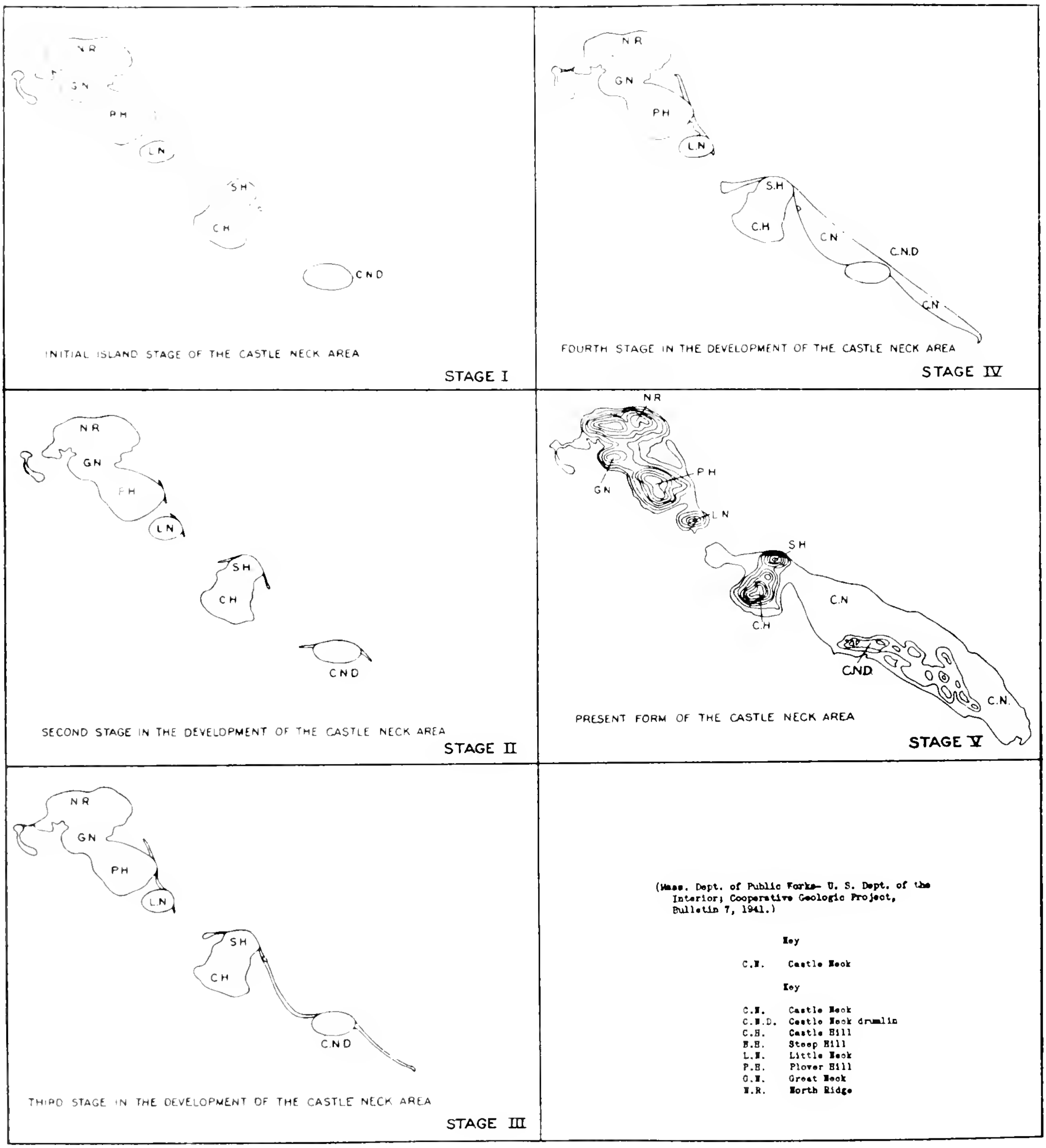
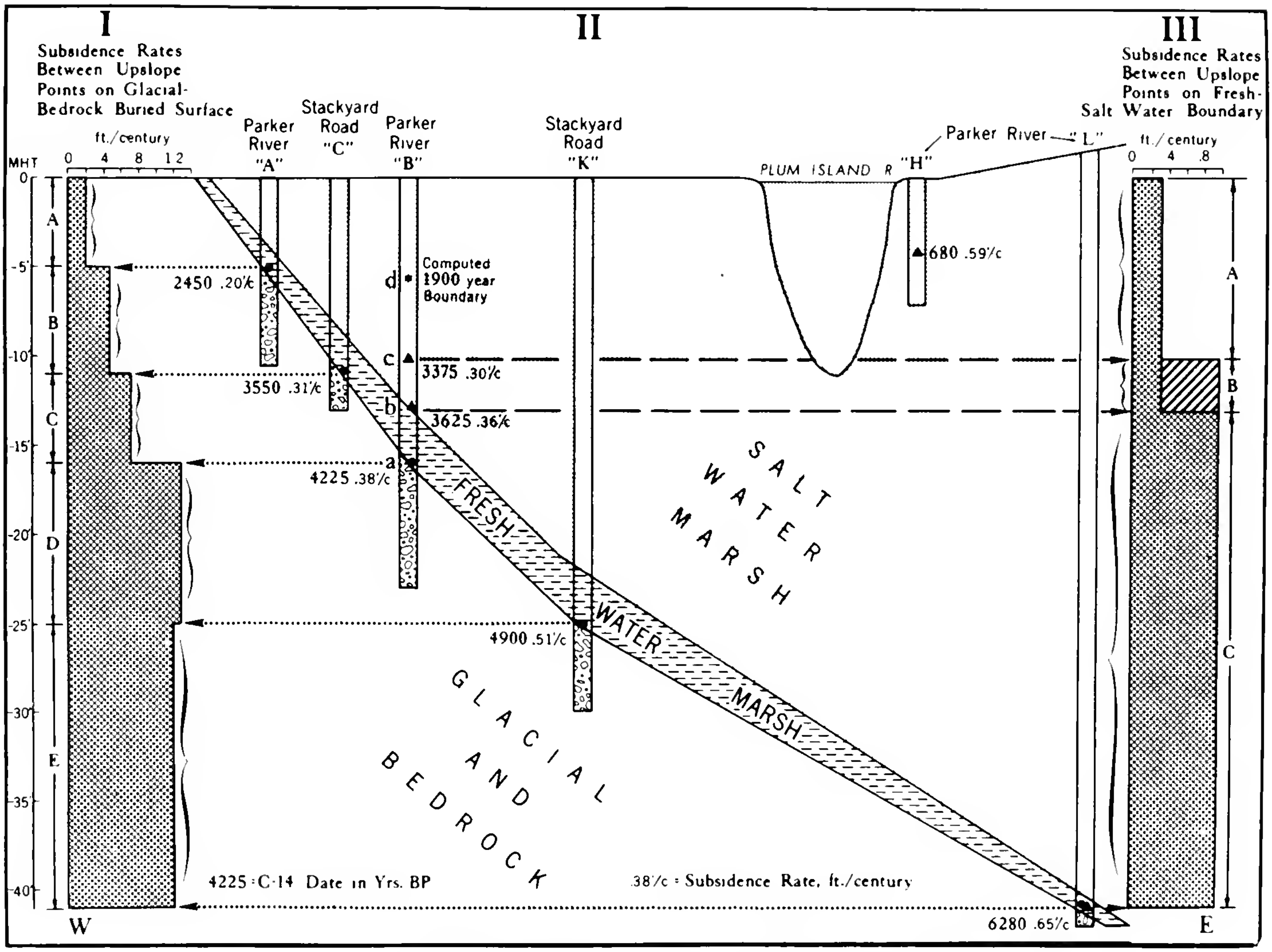


Figure 10. Diagram showing 5 stages in the evolution of Castle Neck and neighboring beaches.



Cross-section of Plum Island marsh correlated with radiocarbon dated peat. I. Indicates subsidence rates calculated on fresh marsh peat between upslope points. II. Shows marsh development rates calculated from position of dated peat to the surface. III. Portrays subsidence rates between the upslope fresh-salt water boundary.

after McIntire and Morgan

Figure 11. Cross-section of Plum Island marsh correlated with radiocarbon dated peat.

(7) grain size of beach and eolian sand (Plum Island, Castle Neck, etc.)

MAPS

(1) U.S. Dept. Interior, Geological Survey, Gloucester Quad., Massachusetts
(2) U.S. Dept. Interior, Geological Survey, Marblehead North Quad., Mass.
(3) U.S. Dept. Interior, Geological Survey, Ipswich Quad., Mass.
(4) U.S. Dept. Interior, Geological Survey, Newburyport East Quad., Mass.

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TRIP B

GEOLOGY OF ROUTE 93 FROM PINE HILL, MEDFORD, MASSACHUSETTS TO ANDOVER, MASSACHUSETTS

Robert F. Boutilier, Boston University

Introduction

The trip begins in the Middlesex Fells at Pine Hill, Medford. The Fells is a relatively uplifted area with up to 200' of relief. Cropping out on the Fells are the Lynn volcanics, Newburyport quartz diorite, Marlboro formation, Westboro quartzite, a volcanic breccia, and numerous dikes including the Medford diabase dike. Proceeding north, and leaving the Fells, one comes successively to the Reading granite (Dedham granodiorite ?), Salem gabbro-diorite (metalavas ?), Andover granite and associated metamorphic rocks, and the Merrimack quartzite. A generalized stratigraphic column, adapted from Emerson (1917, p. 17), Clapp (1921, p. 14-15), and LaForge (1932, p. 14-48), is shown below:

Triassic	Diabase dikes (Medford diabase dike)
Carboniferous	Andover granite Merrimack quartzite
Devonian	Lynn volcanics
Early Paleozoic	Salem gabbro-diorite complex
Precambrian (?)	Westboro and Marlboro

Portions of the Boston North, Lexington, Reading, Wilmington, and Lawrence quadrangles will be studied.

The Newburyport quartz diorite will be the first unit studied. The Newburyport is regarded as a portion of the Salem gabbro-diorite complex which includes three phases: Salem gabbro-diorite, Newburyport quartz diorite, and Dedham granodiorite. The complex is characterized by sudden changes in texture from coarse to fine and in composition from basic to acidic. LaForge (1932, p. 22) describes the unit in the following manner:

> The (Salem gabbro-diorite rocks) are so intricately mixed, by both intrusion and intergradation, that it is impossible to map them separately except on a very large scale ...

> No sharp lines can be drawn on the ground or in the laboratory between the rocks of these subgroups and the inclusion of a mass of rock in one or another is often a matter of personal choice.

The origin of the rocks is still not clear particularly the changes in texture and composition. Clapp (1921, p. 21) proposed an origin for the rocks which relied on overall field relationships:

> The upper part of the batholith is the most felsic,... and is everywhere of granodiorite, which passes downward through quartz-diorite into gabbro-diorite, the staple rock of the batholith. This arrangement of the three subalkaline types accords with their respective densities, the uppermost, the Dedham granodiorite, being the lightest. It is doubtless the result of magmatic differentiation, which proceeded under gravitative control. The parent magma was doubtless basaltic and its differentiation is believed to have occurred in place through fractional crystallization.

LaForge (1932, p. 68) proposes a different variation of the magmatic crystallization hypothesis:

> The differentiation must necessarily have taken place in a primary magmatic chamber that probably underlay the whole region. Gravitative fractionation may have been a considerable factor but the differentiation was also due partly to assimilation of the invaded rock. Both processes would tend to cause a progressive change in the composition of the parent magma which was basaltic at first toward the silicic end of the scale.

The rocks on the Fells have compositions corresponding generally to those of the Newburyport quartz diorite. The average rock consists of orthoclase, andesine-labradorite, hornblende and quartz with some pyroxene and epidote. The complex is dated as Early Paleozoic because it is non-conformably overlain by the Lynn volcanics which are thought to be Devonian in age.

A major portion of the Fells is composed of the Lynn volcanics. The volcanics are dated as Devonian on the basis of a lithologic correlation. LaForge (1932, p. 29) states that the Newbury volcanic complex is dated as Lower Devonian because of marine fossils (identity not specified) which were found in an intercalated calcareous shale. The Lynn volcanics resemble the Newbury volcanics in texture and composition and are, therefore, regarded as being of the

same age. At Pine Hill, Medford, which provides the best exposure of the unit, the rocks are typical pink to violet felsites with greenish phenocrysts of feldspar. The phenocrysts are generally euhedral to subhedral orthoclase or quartz. The groundmass is an intricately interlocked mixture of fine-grained quartz and orthoclase.

The Marlboro formation and Westboro quartzite as mapped by LaForge crop out on the Fells north of Spot Pond. The units as described by Emerson (1917, p. 31) are vague and poorly defined, consisting of several rock types including volcanics as well as quartzites. The exposures to be studied on this trip are generally of the volcanic type. The rocks show distinct stratification and are extremely fine grained. They are composed largely of orthoclase as determined by staining techniques. Parts of the unit may correlate with the Lynn volcanics. The unit is closely associated with a volcanic breccia (?). Unfortunately, the new road cuts are slightly to the east of the contact of the breccia with the surrounding rock.

The only other rocks occurring on the Fells are Triassic dikes. The most famous of these is the Medford diabase dike which crops out just north of Pine Hill, Medford. The dike reaches a maximum thickness of about 300' in the Pine Hill vicinity. The dike can be traced only two miles by its characteristic fine-grained feldspar weathering product. All traces of the dike are lost about 200 yards east of the highway in the woods. An interesting discussion concerning the weathering of the dike took place in the early 1930's. Some geologists such as Lane and Wolf (1932) believe the weathering is preglacial; others such as Billings and Roy (1933) believe the weathering has been postglacial. An excellent early description of the dike was provided by Wilson (1901). The dike is essentially composed of large (6-8mm.) euhedral crystals of plagioclase (labradorite-andesine) intergrown with augite in a classic diabasic texture.

South of Route 128 rocks mapped by LaForge as Dedham granodiorite and Salem gabbro-diorite crop out. The rocks mapped as Dedham granodiorite are pink microperthitic microcline granites and syenites and are here simply described as Reading granite. The rocks mapped as Salem gabbro-diorite may correlate with dioritic rocks cropping out to the south on 128 which show definite volcanic structures. The rocks are on this basis described as metalavas. The granite is intrusive into the metalavas and is composed of microcline microperthite, plagioclase (albite-oligoclase) and quartz. The perthite is apparently of the replacement type since some of the grains are non-perthitic while others are almost completely replaced. The rock is highly fractured. Feldspar grains are commonly sheared and undulatory extinction is well developed. The surrounding metalavas show much evidence of faulting. The metalavas are composed of pyroxene, amphibole, and andesine. The texture is fine- to coarse-grained allotriomorphic granular. North of 128 the granite grades into syenite by loss of quartz.

Immediately north of 128 in the vicinity of the Ipswich River outcrops are scarce due to burial beneath a thick covering of glacial outwash. However, in Wilmington, elevations increase and outcrops of the Andover granite and associated metamorphic rocks can be studied in continuous exposure for over six-tenths of one mile. As the granite is approached, the grade of metamorphism increases. Hornblende-biotite schist, quartz-orthoclase-hornblende gneisses and migmatites are abundant. The original nature (probably sedimentary) and age of the metamorphics is not clear. The Andover granite is characterized by a white to gray color and a peculiar alternation of pegmatitic and aplitic layers. The granite is composed of microcline, quartz, muscovite and some albite. Locally biotite and garnet are abundant. The feldspar is not perthitic and there is little evidence of shearing as compared with the Reading granite. An augen texture is developed in the granite near its northern contact with the Merrimack quartzite. The granite is dated as Late Carboniferous since it intrudes the Merrimack quartzite. Clapp (1921, p. 20) states that the Merrimack quartzite is continuous with similar rocks near Worcester which were dated by fossils as Carboniferous. The Andover granite is probably close in time to the Chelmsford, Quincy and Rockport granites.

Road Log

The trip begins at the intersection of Route 93 and Route 28 at Pine Hill, Medford. Mileage begins at the first underpass on Route 93 going North. The trip will generally proceed north up the highway and then return south along the highway. Thus, we will not be required to cross the highway. Extreme caution is urged in examining the roadcuts because of the danger from falling rocks and traffic.

Mileage	Description
0.0	Intersection Rt. 93 and Rt. 28. First overpass on Rt. 93.
0.5	<u>Stop 1</u> - Outcrop of Medford diabase dike and of typical Newburyport quartz diorite. The dike shows the characteristic confinement of weathering to joint surfaces. Even near its contact with the diorite the dike is still coarse textured. Note the sudden changes in texture and in composition of the diorite. This is quite characteristic. Proceed North on Route 93.
0.9	<u>Stop 2</u> - Example of spheroidal weathering basalt

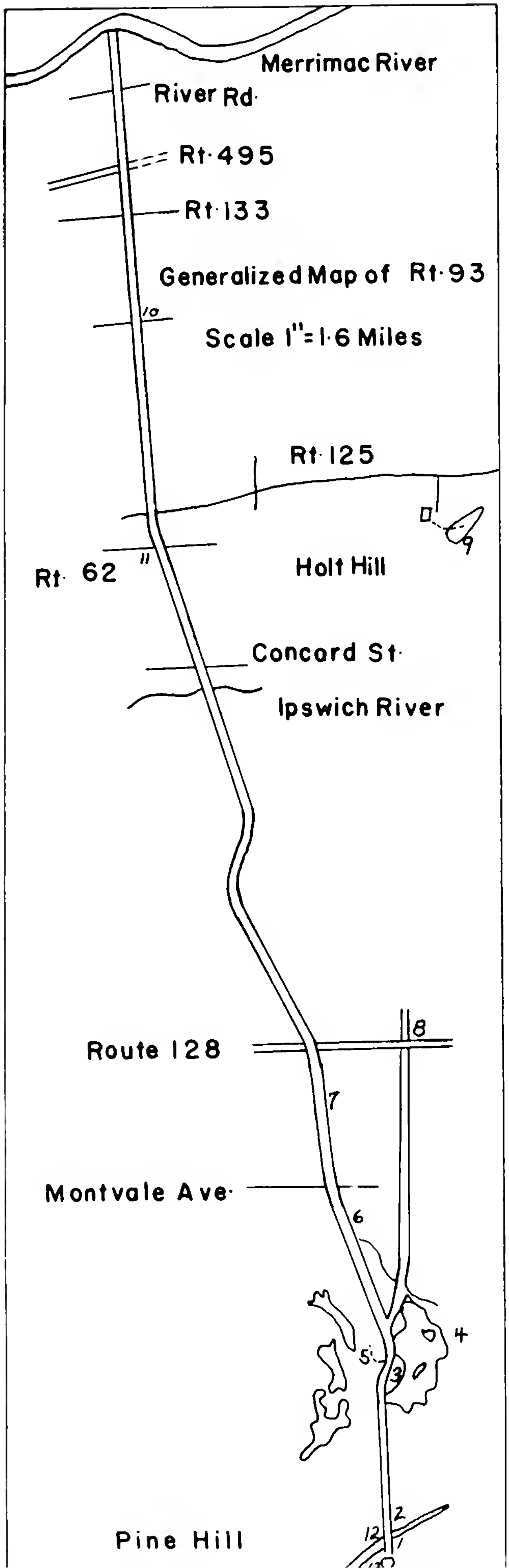


Figure 1.

Stop Locations and Descriptions

Stop 1 - Newburyport Quartz Diorite and Medford Diabase Dike.

Stop 2 - Newburyport Quartz Diorite and spheroidal weathering of basalt dik

Stop 3 - Marlboro? and Westboro

Stop 4 - Marlboro?

Stop 5 - Volcanic breccia well exposed in woods.

Stop 6 - Newburyport Quartz Diorite

Stop 7 - Reading Granite and Salem Gabbro-Diorite?

Stop 8 - Salem Gabbro-Diorite? Intensive faulting

Stop 9 - Lunch at Holt Hill, highest point in Essex County

Stop 10 - Andover Granite

If we can go to the Brox Trap Roc Quarry in the Dracut Diorite then stops 11, 12, and 13 will be omitted. The quarry is reached by continuing north on Route 93 past stop 10 to the Merrimack River and then turning left alon Route 110 to Dracut.

Stop 11 - Contact zone of Andover Granite with Wilmington Metamorphic Rocks.

Stop 12 - Contact of Medford Diabase Dike, Lynn Volcanics, and Newburyport Quartz Diorite.

Stop 13 - Lynn Volcanics intuded by Triassic Dikes.

dike. The dike is probably an offshoot of the Medford diabase dike. The weathering of the dike starts from the corners of the intersections of joints and proceeds inward. The country rock is Newburyport quartz diorite. Fault surfaces are well exposed in the northern section of the outcrop.

Proceed North on Route 93.

1.4 Stop 3 - Roadside rest area. We will walk the length of the outcrop. Typical exposure of volcanic material mapped as Marlboro and Salem gabbro-diorite. The black angular inclusions become larger and more numerous to the north in the outcrop. Note that the contacts are sometimes gradational and at other times quite sharp.

Proceed North along Route 93 to next exit.

1.7 Turn right at exit 22 and follow signs to Middlesex Zoo. Highway becomes divided after Zoo.

3.3 Make a U turn around rotary going back along the other side of the divided highway toward the Zoo.

3.4 Stop 4 - Well-bedded Marlboro formation. We will walk about 0.2 of a mile along the outcrop to see an exposure of volcanic breccia.

Proceed back toward Zoo and past it to traffic lights.

4.3 Traffic lights turn left; follow signs for Route 28 not signs for Route 93.

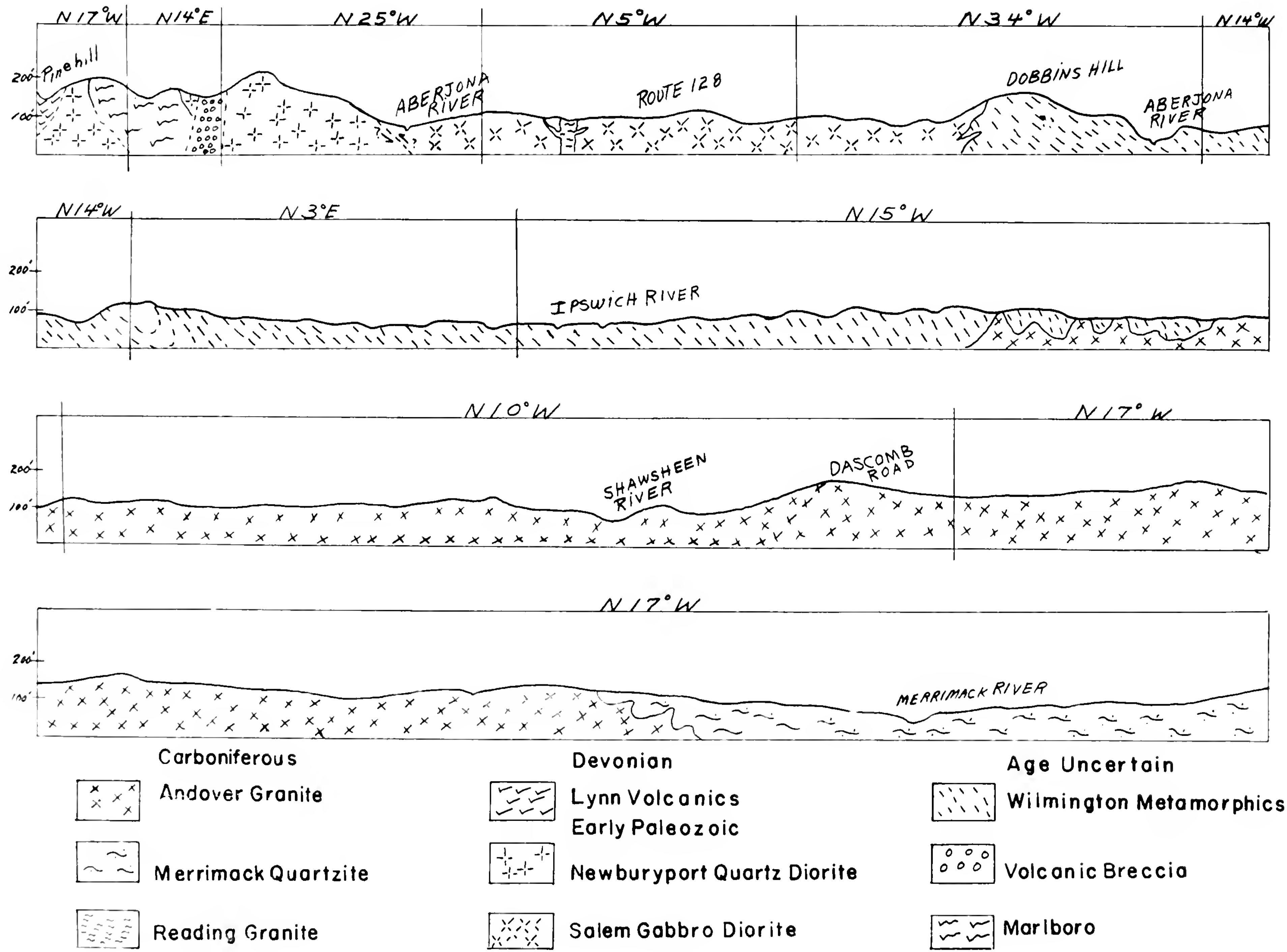
5.0 Turn right on Bear Hill road (sign says "Open only to M.D.C. vehicles").

5.2 Road branches into three parts. Keep right following white fence.

5.4 Stop 5 - Volcanic breccia outcrops in woods to the right and left. Best exposure is in valley on the right of the road.

Turn around and return to stop lights.

Figure 2. CROSS SECTION ROUTE 93 PINE HILL, MEDFORD TO LAWRENCE



6.4	Traffic lights turn left following signs to Route 93. Nordbergs Restaurant will be on your right and the M.D.C. swimming pool on your left after you make the turn.
6.6	Orchard Street - A good example of a porphyritic dike exposed on the left up the hill. Country rock is Newburyport quartz diorite.
6.7	Turn left onto Route 93 at entrance marked "North Wilmington-Lawrence".
7.3	Stop 6 - Outcrop of Newburyport quartz diorite. Numerous fault surfaces can be seen. On a clear day a good view straight ahead of the New England Upland Erosion surface with monadnocks. Proceed North along Route 93.
7.4	View on left of Blueberry Hill Quarry. Over two dozen minerals have been reported from this quarry.
8.4	Stop 7 - Reading granite intruding rocks regarded as possible metalavas. Rocks as mapped by LaForge are Salem gabbro-diorite(?). Microcline spots are developed throughout the rocks. Proceed North on Route 93 towards 128. Take first exit onto 128 north.
9.0	Turn right at 25N onto Route 128. Proceed along Route 128 to next intersection. The roadcut is in the metalavas. However, the same type of rock can be more safely studied at the next intersection where a cloverleaf has been abandoned due to widening of Route 128.
10.0	Turn right at exit 36N labelled Route 28 - Reading. Continue on Route 28 underneath Rt. 128.
10.3	Stop 8 - Make a right hand turn onto South St. Park in field on corner. Walk to center of abandoned cloverleaf. Watch out for traffic. The northern section of the cloverleaf shows highly polished slickensides. The faulting is of a block type in this

section. The bedrock is typical Salem gabbro-metalavas(?).

Return onto Route 128 at Woburn South Shore entrance directly across the street from where you are parked.

11.2 Take exit 37N from Route 128 onto Route 93. The exit is labelled Lawrence. Follow Route 93 to next stop.

12.5 Dobbins Hill on right is a drumlin. The gullying has resulted from oversteepening of the slope by the road cut.

12.9 Drumlin with exposed bedrock core on right.

15.2 Ipswich River flowing over thick covering of glacial outwash.

16.2 Increasing grade of metamorphism as Andover granite is approached.

17.4 Take exit 29 to North Andover and Haverhill Route 125.

18.3 Gravel on right and left marks the end of the Indian Ridge esker which divides into a series of distributaries ending in the outwash plain seen near the Ipswich River.

19.6 On left is erratic boulder with pink microcline crystals up to six inches in length.

20.1 Intersection of Route 125 and Route 28. Cloverleaf is cut in contact of Andover granite with Salem gabbro-diorite.
Proceed along Route 125.

22.9 Turn right on Prospect Street. Follow signs for Charles Ward Reservation. This turn is just after you pass Texaco station on your left.

23.2 LUNCH

Park on right for reservation. We will walk to the top of the drumlin called Holt Hill. Holt Hill is 420' high and is the highest point in Essex County. Mt. Monadnock is visible from the fire-tower on a clear day. On the adjacent drumlin, Boston Hill (385'), MIT has constructed a radar station.
Return along Route 125 to Route 93.

28.6 Left hand turn onto Route 93. Sign labelled Salem-Lawrence.

29.2 Stop 10 - Outcrop of Andover granite in middle of highway. Watch out for traffic. The outcrop illustrates the distinct alternation of pegmatitic and aplitic layers characteristic of the granite. Garnet is abundant in many of the finer-grained layers.

At the time this is written it is not known if we will be able to visit a quarry in the Dracut diorite. The quarry is of interest since nickel was once mined there. On the assumption that we will be able to visit the quarry and for those who may be able to travel there on their own, directions are given to the quarry.

31.4 Shawsheen River - a tributary of the Merrimack River.

32.0 Exit 30 to Dascomb Road. Andover granite well exposed in road cuts under highway. If we do not go to the quarry we will make a U turn here and go back along 93 towards Boston.

38.4 Cross Merrimack River and turn right at exit 34. Follow traffic circle until you come to sign for Route 110 - Lowell. Follow Route 110 along the Merrimack River towards Lowell.

42.2 Right turn at Brox Trap Rock Quarry.

Return along Route 110 to Route 93 and then south on Route 93 towards Boston.

52.7 Stop 11 - Intersection of Route 62 and 125 Con-

tact zone of Andover granite with metamorphics of uncertain origin.

57.0 Overturned synclinal structure shown on right in tuffs and quartzites.

63.0 Stop 12 - Contact of Medford diabase dike with Newburyport quartz diorite. Slightly to the south of this contact, the contact of the Lynn volcanics with the Newbury quartz diorite can be observed. The relationship here suggests the diorite is younger than the volcanics unless overturning has occurred.

63.2 Stop 13 - Excellent exposure of Lynn volcanics cut by numerous basalt dikes.

TRIP B

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TRIP C

THE SQUANTUM FORMATION. PALEOZOIC TILLITE OR TILLOID ?

Dabney W. Caldwell, Wellesley College

The origin of the Squantum formation has long been a controversial subject in the geology of the Boston Basin area, Massachusetts. Two points of view have been expressed: (1) the Squantum formation is a Paleozoic tillite and, (2) the Squantum formation is not a Paleozoic tillite. The purpose of the present field trip is to examine the field evidence on which these views are based. Following a description of the geologic setting of the Squantum formation and a brief review of some of the previous work dealing with the Squantum formation, the results of some recent studies of the texture will be presented. Finally, a log of the field trip stops will be included.

Geologic Setting and Stratigraphic Position of the Squantum Formation

The traditional view of the Boston Bay group of sediments, to which the Squantum formation belongs, is that it comprises, in stratigraphic order, the Roxbury conglomerate, the Squantum tillite and the Cambridge argillite. These rocks overlie the Mattapan volcanics and the Dedham granodiorite and are exposed in the Central Anticline and repeated several times by faulting (Billings, 1929 LaForge, 1932). More recently Dott (1961) and Rahm (1962) have suggested that these units are more intimately related and are characterized by interfingering and facies changes. Billings (1929) considered the Squantum formation to be a separate, mappable rock unit and explained the various repetitions in terms of faulting, whereas Dott (1961) suggested, in effect, that there may exist more than one Squantum "tillite" bed within the Roxbury and Cambridge lithologies.

The age of the Squantum formation and the associated Boston Bay group has not been settled and yet is very pertinent to any discussion of a glacial or non-glacial origin of the formation. Those workers who have proposed or accepted a glacial origin have tended to place the Squantum formation within the Pennsylvanian or Permian (Sayles 1914, Emerson 1917, Billings 1929, Billings et al., 1939), whereas Dott (1961), who proposed a non-glacial origin, believed the Squantum to be Mississippian or Devonian in age. Analogy with the Permian Gondwana formations of India and the southern hemisphere and the apparent similarity between the Boston Bay Group and Carboniferous and Permian strata in Rhode Island has led to the designation of the Squantum as being of Permian or Permo-Carboniferous age, according to Dott (1961).

Origin of the Squantum Formation

There are characteristic features common to some exposures of the Squantum formation and many Pleistocene tills, such as poor sorting, lack of stratification, and relative abundance of clay matrix compared with the gravel and larger sizes. Sayles (1914) found striated pebbles in the Squantum formation but apparently is, along with Lahee (1914), the only worker to do so. Because of similarity between Pleistocene till and the Squantum formation and because a late Paleozoic glaciation had been established in the southern hemisphere and India, Sayles (1914), after extensive field work and consultation with other workers, proposed a glacial origin for the Squantum formation, which became established in the literature as the Squantum tillite. Earlier, Dodge (in Mansfield, 1906) had suggested that parts of the Roxbury formation were of glacial origin.

Later Sayles (1916, 1919) proposed that the overlying Cambridge argillite was also of glacial origin and pointed to the similarity between the rhythmical banding found in the Cambridge argillite and in Pleistocene varved sediments. Sayles apparently became the authority upon which later workers based their acceptance of a glacial hypothesis.

Dott (1959, 1961) has been a leading proponent of a non-glacial origin of the Squantum formation and has disagreed with many of the accepted views dealing with the formation. As has been mentioned, he does not accept a late Paleozoic age for these rocks and also finds many features which he feels are more reminiscent of subaqueous, partly volcanic mud flows or slides than of glacial till. Dott (1961, p. 1300) has compared the compositions of the larger fragments of the Squantum and Roxbury and finds them to be essentially the same and believes the Squantum to be reworked Roxbury sediment with some mud added during the reworking. As the clasts in both the Squantum and Roxbury formations are similar in composition and of local origin, a glacial origin for the Squantum is not only unnecessary but improbable. Dott also points out that the lack of any striated pavement beneath the Squantum and its apparently unique position in North America make a glacial hypothesis more untenable.

Many of the exposures of the Squantum mentioned by Sayles (1914) are gone but the most important are still preserved and will be visited on the field trip as will most of those mentioned by Dott (1961).

Shape of Clasts in the Squantum and Roxbury Formations

Regardless of the opinion held by previous workers concerning the origin of the Squantum formation, most have compared the Squantum formation with the Roxbury: those who have believed in a glacial origin have stressed the greater

angularity of the pebbles and cobbles in the Squantum as compared with those in the Roxbury conglomerate, whereas Dott (1961, p. 1300) believes ... "that Squantum fragments are not greatly different in shape from those of the Roxbury...". In order to come to some objective conclusion in the matter, the writer has measured the shape of several hundred cobbles and pebbles from both the Squantum and the Roxbury formations and the results of the measurements are presented below.

Smoothed surfaces have been produced by Pleistocene glaciation or by jointing on many outcrops of the Squantum and the Roxbury formations and it is possible to measure the roundness of clasts directly from the outcrop, following the method described by Krumbein and Pettijohn (1938, p. 295) Roundness is expressed as

$$\text{Roundness} = \frac{\text{Average radius of corners and edges}}{\text{Radius of maximum inscribed circle}}$$

The average radius of sharp corners and edges is small compared with the size of the fragment as a whole, and the roundness is low. With increasing rounding of the edges, the average edge and corner radius approaches the radius of the fragment and the value of the roundness approaches 1.0. According to Pettijohn (1957, p. 59), the common terms used to describe roundness have the roundness values shown in Table 1.

TABLE 1 - Roundness values of common roundness terms

Angular	=	0	-	0.15
Sub Angular	=	0.15	-	0.25
Sub Rounded	=	0.25	-	0.40
Rounded	=	0.40	-	0.60
Well Rounded	=	0.60	-	1.0

At each locality, the roundness of 100 fragments was measured and the median roundness, the mean roundness and the standard deviation were determined. These data are presented in Table 2.

TABLE 2 - Roundness and standard deviation of clasts in the Squantum and Roxbury formations

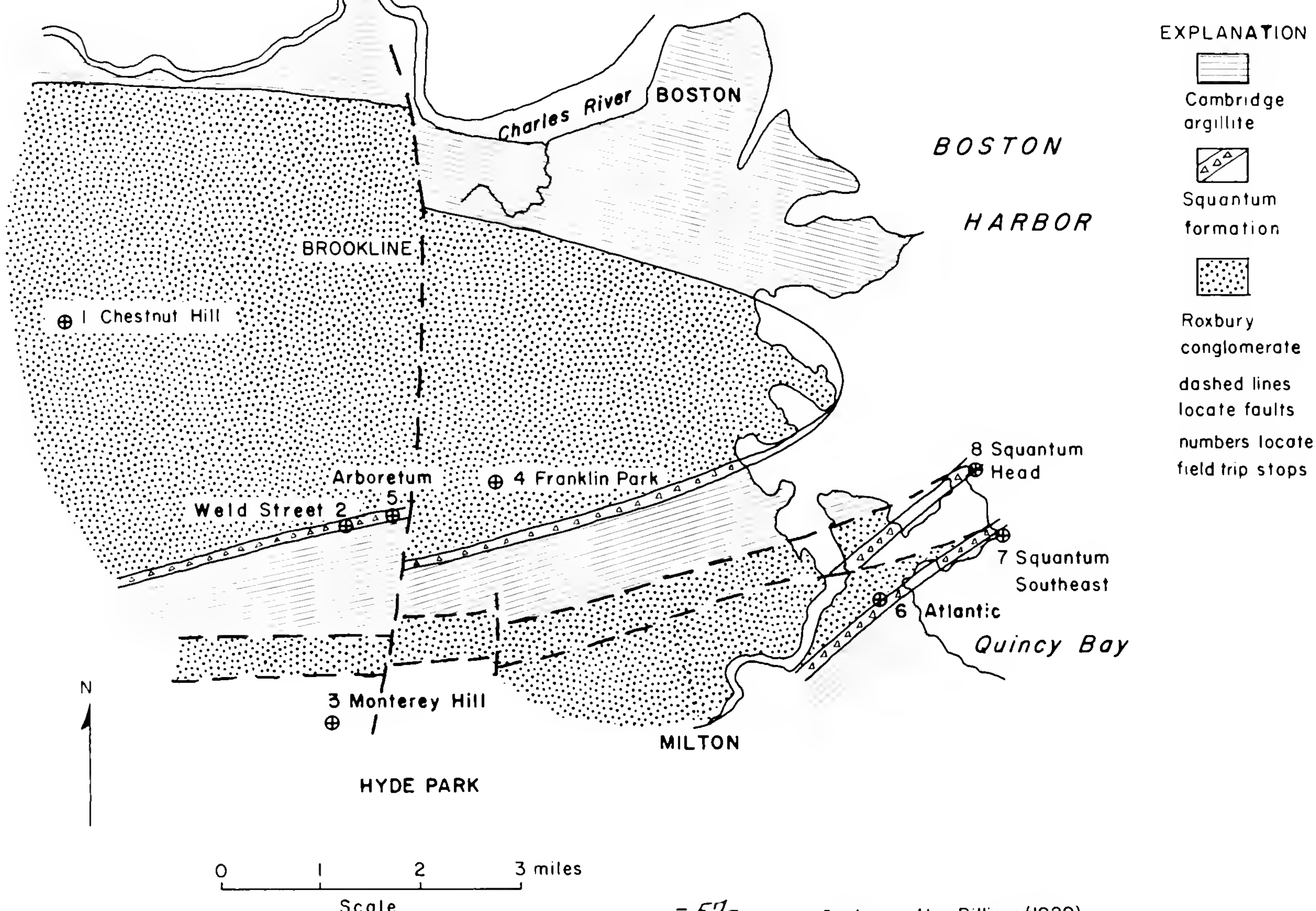
	LOCALITY	Roundness MEDIAN	Roundness MEAN	Standard Deviation
ROXBURY	Chestnut Hill	.49	.54	.16
	Franklin	.46	.52	.14
	Atlantic	.47	.53	.15
SQUANTUM	Weld Street	.45	.53	.23
	Arboretum	.45	.54	.23
	Atlantic	.44	.52	.24

This analysis indicates that, as expressed by "average" roundness, median or mean, there is little significant difference between the Squantum and Roxbury clasts but a significant difference in the dispersions of roundness values about the mean roundness values. Stated in words, it may be said that in the Squantum, there are a greater number of both angular and well-rounded fragments than in the Roxbury. It is interesting to note that as far as average roundness is concerned both formations may be characterized as having clasts which are rounded (roundness 0.4 to 0.6).

The results of these roundness measurements, as they may pertain to the origin of the Squantum, appear to be ambiguous: on the one hand, the similarity in average roundness measured in the Squantum and Roxbury formations suggests a similar abrasion history and by implication supports a non-glacial origin. On the other hand, the consistent difference in the range of roundness values, as measured by the standard deviation (see Table 2), implies that the units in question have different origins. Although this difference in roundness does not, of course, necessarily support a glacial origin for the Squantum, neither does it necessarily support an origin by subaqueous mass movement, as suggested by Dott (1959, 1961). Studies by Wentworth (1936) of the shape of glacial cobbles showed that 82% were well-rounded or moderately rounded but only 18% were angular or sub-angular. This suggests that angularity is not characteristic of glacially abraded fragments in the first palce and that the foregoing discussion may be beside the point, after all.

<u>Log of Field Trip Stops.</u> The approximate location of these stops is shown on the accompanying map.

Figure 1. MAP OF THE BOSTON AREA
SHOWING
LOCATION OF FIELD TRIP STOPS



Geology after Billings (1929)

STOP 1 - Chestnut Hill - This stop was chosen as a typical and convenient exposure of the Roxbury conglomerate On hill summit east of road, the Roxbury consists of cobblestone and pebble conglomerate with obscure bedding In road cut the formation is more variable with several sandy beds and shale partings Obscure ripple marks, current bedding and graded bedding are visible

STOP 2 - Weld Street Squantum tillite - Typical Squantum lithology is exposed in an old quarry Note relative abundance of fine matrix as compared with Roxbury Boulders up to 2 feet in diameter occur here. In these exposures, Sayles (1914) found a striated pebble. Obscure bedding is locally present

STOP 3 - Monterey Hill _ Mattapan (?) volcanic agglomerate[1] Exposures of Dedham granodiorite overlain by a volcanic agglomerate containing fragments of the Dedham These rocks grade upward into sediments which resemble the Roxbury conglomerate. Accepting for the moment Dott's (1961) theory of tectonic islands contributing volcanic material, subsequently reworked by subaqueous slides to form the Squantum formation, we have here evidence that such activity did occur in the Boston Basin. Unfortunately the stratigraphic position of these rocks is unknown, although they apparently underlie the Roxbury and obviously overlie the Dedham

STOP 4 - Franklin Park - Numerous exposures of the Roxbury conglomerate, which here is somewhat coarser in texture than is normal for the formation, although sandy beds are present. This stop is included in order that a further comparison between the Roxbury and Squantum may be made

STOP 5 - Arnold Arboretum - Squantum tillite. Many excellent exposures showing typical Squantum lithology on high ridge at south end of Arboretum. High percentage of greenish matrix. Bedding is for the most part obscure at best, although there are some sandy layers Casts of well-rounded boulders up to 3 feet in diameter are common.

Note: We have permission to eat our lunch on the grounds and will do so before or after examining the rocks in the Arboretum, depending upon what time we arrive on the grounds. Rest rooms at the greenhouses will be opened for us between 12:00 and 1:00 P.M.

STOP 6 - Atlantic Locality - Squantum and Roxbury formations are separated by Cambridge-like sediments. The lower part of the Squantum contains large fragments of this Cambridge-like sediment and exposures of this relationship constitute some of the most telling field evidence which Dott (1961) presents against a glacial origin for the Squantum sediments. Slump structures, load casts graded and cross bedding are present.

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[1] The writer is indebted to Rev James W. Skehan, S.J. for bringing this locality to his attention and to Mr. George Saulnier for guiding him in the area

STOP 7 - Squantum Southeast - Recent construction has obscured many significant parts of this locality but Cambridge argillite overlying the Squantum is still exposed Unfortunately, the fine exposures figured by Sayles (1919) of slump structures within the Cambridge have been covered

STOP 8 - Squantum Head - Cambridge argillite here overlies the Squantum formation and is also exposed beneath the Squantum. This repetition is explained by Billings (1929) as being the result of faulting. Roxbury-like beds occur within the Squantum formation proper and small scale slump features are present within the Cambridge beds.

TRIP C

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TRIP D

SOME MINERAL LOCALITIES WEST OF BOSTON

C.S Hurlbut Jr - Harvard University

Mineral localities in the neighborhood of Boston have never been numerous, but as the city has expanded and the suburbs built up some have become inaccessible and others have disappeared beneath roads and apartment buildings. Moreover as farming has been abandoned in the outlying area and cultivated land has returned to forest even some of the more remote localities are difficult to find; and once located the minerals that can be found are few. This excursion therefore, cannot be considered a mineral collecting trip, but rather a visit to some mineral localities of historic interest

The following itinerary begins at the junction of Routes 2 and 128 West of Boston as shown by the accompanying sketch map.

Itinerary

EN ROUTE TO STOP 1, beginning at Route 2 and 128

6.8 miles west on Route 2 to junction with Route 62

7.1 miles to Stow on Route 62

3.7 miles west of Stow on Route 117 (.7 miles beyond General Radio Corporation) to Stop 1.

Stop 1. Bolton Lime Quarry

This is the largest and best-known of a series of quarries in the string of metamorphosed dolomitic limestone bodies which extends from Bolton twenty miles northeast to Chemsford. The limestone bodies are roughly lens-shaped and are encolsed in the biotite gneiss of the Nashoba formation (Carboniferous).

The limestone from this and the other quarries has been used intermittently in the manufacture of plaster, cement and agricultural lime since colonial times. But except for a brief period of activity about 25 years ago, there has been no quarrying in the twentieth century. As a result of this long period of disuse, most of the outcrops and dumps are overgrown and are difficult to find

BEWARE OF POISON IVY

In the main quarry, however exposures are still good, and a represen-

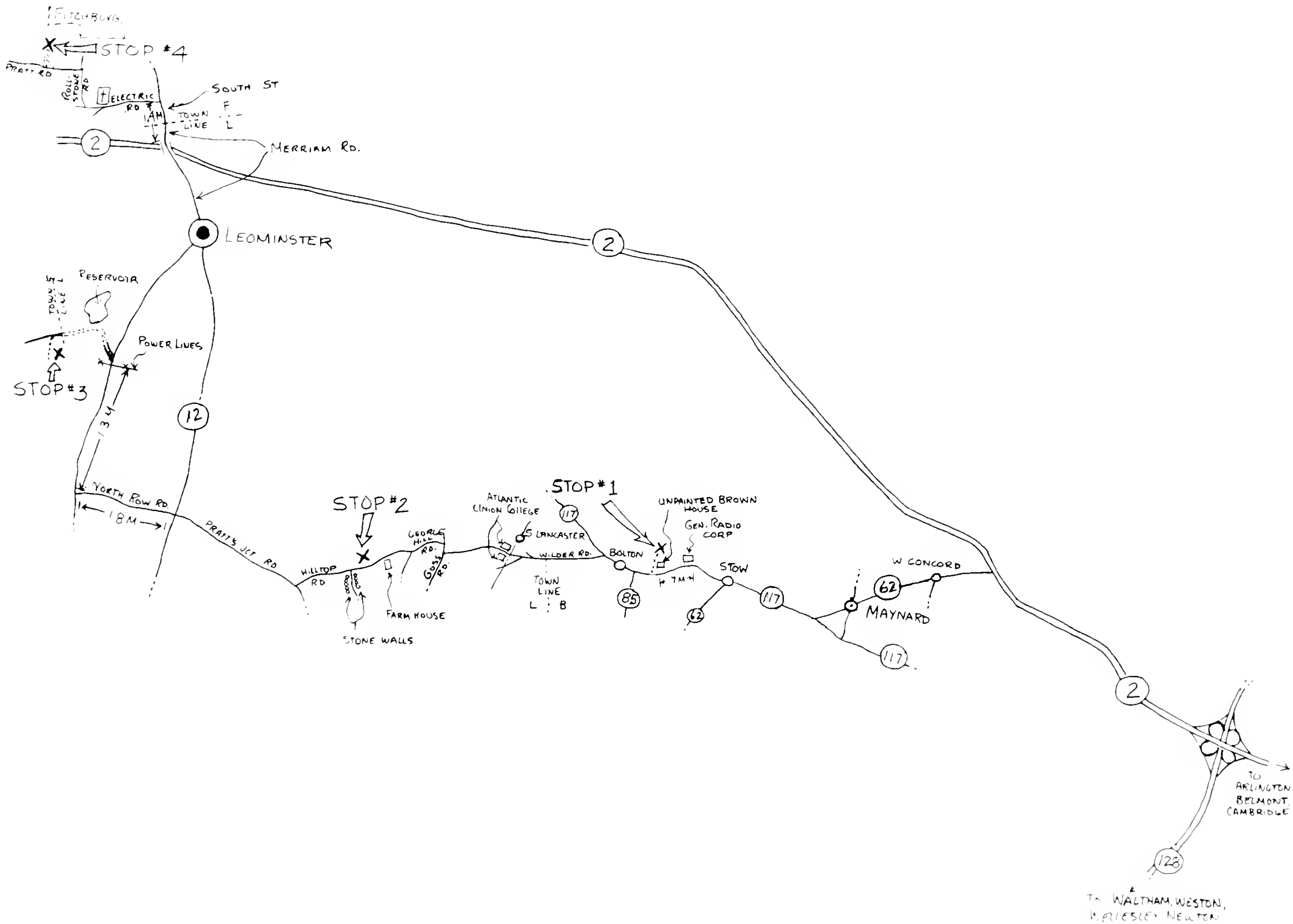

Figure 1. Stop locations for Trip D.

tative suite of the typical minerals of this classic locality can be obtained fairly easily.

Not clearly visible on the quarry face, but sometimes observed on single boulders or even hand specimens, is the distinctive zoning described by Palache and Pinger (1923) Next to the gneiss is a layer varying from a few inches to sixteen feet in width, of scapolite-rich limestone, then a layer of diopside and tremolite-rich rock and finally a zone containing abundant olivine ("boltonite"), which grades into normal limestone.

Minerals

Scapolite - coarsely crystalline aggregates and single crystals, the latter being imbedded in quartz or calcite. Color varies from white to pinkish lavender. Crystals are generally rough, stout prisms, and have a distinctive silky luster due to the intersection of the prismatic cleavages.

"Boltonite" - actually a variety of forsterite It occurs in the limestone as small gray to colorless grains often altered to a yellowish color. Note the good pinacoidal cleavage.

Feldspars - chiefly microcline found in pegmatites associated with scapolite and phlogopite. Some andesine also present.

Diopside - abundant as light green grains and subhedral to euhedral crystals in the contact zone of the limestone.

Tremolite-actionolite - pale green to dark green blades and needles abundant in the border zone of the deposit.

Phlogopite - golden brown flakes Scattered through limestone

Sphene - in typical dark brown lens-shaped crystals dispersed in limestone, chiefly in the diopside-rich zone.

Garnet - small red grains associated with scapolite.

Chondrodite - yellow grains concentrated in olivine zone.

Apatite - bright blue-green grains and euhedral crystals up to three inches in length Often associated with scapolite.

Spinel - small blue-gray octahedrons associated with chondrodite in the olivine zone.

Other accessory minerals identified at Bolton in small amounts: allanite petalite pyrite graphite rutile arsenopyrite chalcopyrite pyrrhotite fluorite serpentine and talc

Reference: Palache C and Pinger A W 1923. Scapolite Deposit of Bolton Massachusetts: Amer. Min 8: p 153-157

EN ROUTE FROM STOP 1 TO STOP 2

3 0 miles west on Route 117 through Bolton Center bear left on Wilder Road;

3 5 miles to S Lancaster (bearing left after crossing Route 110):

2 5 miles to Stop 2. From S. Lancaster pass through campus of Atlantic Union College to Goss Street at foot of hill Turn right on Goss Street for a few hundred yards then left on George Hill Road Bear right on Hill Top Road and go 1 3 miles to Stop 2.

Stop 2. Chiastolite at Lancaster Massachusetts

The first scientific discussion of this material appeared in the Boston Journal of Natural History in 1834. In his article C.T. Jackson correctly hypothesized that chiastolite was a variety of andalusite. He incorrectly theorized that the typical cross-shaped pattern observed in the cross-section of the chiastolite was due to the aggregation of several separate crystals. It was later shown that the patterns resulted from the selective orientation of carbonaceous inclusions along certain crystallographic directions during the growth of the crystals.

The chiastolite occurs in aluminum-rich horizons in the gray slate of the Worcester phyllite Sandy strata contain insufficient aluminum for the growth of the andalusite and these barren sandy layers in the otherwise chiastolite-rich rock are conspicuous in the outcrops and stone walls of the Lancaster area

Outcrops of the Worcester phyllite once numerous in the pasture land are now largely inaccessible and overgrown. The chiastolite can best be seen in the stone walls bordering the road along which we will pass.

CAUTION In the past over-enthusiastic mineral collectors have been guilty of tearing down the stone walls in their search for chiastolite As a result the local inhabitants are far from being sympathetic to the mineral collector Thus at this locality please do more looking than collecting

Reference Jackson C.T. 1834. An Account of the Chiastolite or Macle of Lancaster Boston Jour Nat Hist p 155-62

EN ROUTE FROM STOP 2 TO STOP 3

1.3 miles west on Hill Top Road, turn right on Pratt's Junction Road;

3.1 miles (crossing Route 12 and continuing on North Row Road to road intersection), turn right on road to Leominster;

1.3 miles turn left on gravel road under power line;

1.2 miles to Stop 3 (.2 miles beyond town line).

Stop 3. The Spodumene Boulder, Sterling, Massachusetts

This is the first locality for spodumene in the United States. The earliest mention of it appeared in an article by G.T. Bowen published in the American Journal of Sciences in 1824, the spodumene having been discovered the year before by a Mr. Nutfall. The boulder is a huge glacial erratic moved from a pegmatite which crops out on a hill more than a mile to the northeast. Smaller boulders containing spodumene are abundant in the woods and stone walls of the area. A boulder train of pegmatite containing spodumene has been traced several miles to the south.

Reference: Bower, G.T., 1824, Analysis of a Siliceous Hydrate of Copper from New Jersey, with a notice of the discovery of two localities of spodumene in the United States. Am. Jour. Sci. and Arts, 8: p. 118-121.

EN ROUTE FROM STOP 3 TO STOP 4

3.7 miles to Leominster Center; retrace route to paved road and turn left to Leominster;

3.7 miles turn left on Electric Road, Fitchburg - follow Merriam Road out of Leominster which becomes South Street in Fitchburg.

1.8 miles to Stop 4. Turn right off Electric Road to Rollstone Road; left on Pratt Road to top of hill.

Stop 4, Rollstone Hill Granite and Pegmatite,
Fitchburg, Massachusetts

Rollstone Hill takes its name from a 112 ton glacial boulder of the Kinsman granite that originally stood on the crest of the hill west of Fitchburg and 400 feet above the town. When quarrying operations imperilled the boulder, it was blasted apart, removed from the mountain, and reassembled on the upper Common of Fitchburg on Main Street where it can be seen today.

At one time three quarries were in operation in the Fitchburg granite of Rollstone Hill, but none of these has been active for many years. Still observable is the pronounced sheeting parallel to the original contour of the hill. The granite, which was used for both dimension stone and concrete aggregate, is a medium-gray muscovite-biotite granite with feldspar grains up to 0.3 inches and mica flakes up to 0.2 inches. The feldspar is chiefly microcline and orthoclase, with subordinate amounts of oligoclase and albite. The quartz is generally light smoky and fractured. Accessories are garnet and apatite.

Of some interest are the abundant pegmatite stringers which cut the granite, especially near the crest of the hill. These pegmatites are generally of simple composition, the major constituents being microcline, quartz, mica, and black tourmaline. The tourmaline often occurs in radiating bundles. Minor accessories are garnet, allanite, beryl and apatite.

Reference: Dale, T.N., 1923, Commercial granites of New England: U.S. Geol. Survey Bull. 738, 228 p.

TRIP E

IGNEOUS ROCKS OF THE SALEM AREA MASSACHUSETTS[1]

Priestley Toulmin, III, U.S. Geological Survey

Igneous rocks of Essex County have been the subject of many detailed studies; publications covering more than local descriptions include those of Clapp (1921), Warren and McKinstry (1924), and Toulmin (1960, 1964) Among the important early descriptive works, the papers of Washington (1898-1899), Wright (1900), and Dale (1908, 1911) should also be mentioned

The rocks to be examined on the present excursion fall into the following groups:

1) Gneisses and plagioclase amphibolites, tentatively referred to the Marlboro formation of probable Precambrian age;

2) Calcalkalic intrusive rocks (gabbro, diorite, quartz diorite, granodiorite) younger than the gneisses and older than the so-called "alkalic" igneous rocks (the calcalkalic rocks are divided into an older and a younger group according to their age relations with the fossiliferous Newbury formation of Late (?) Silurian or Early (?) Devonian age);

3) So-called "alkalic" igneous rocks younger than the preceding groups.

Most of the trip will be devoted to the last-named group, which includes rocks ranging in composition from granitic through syenitic to feldspathoidal and in texture from aphanitic through medium- and coarse-grained to pegmatitic.

In view of the recent publication of detailed descriptions of these rocks (Toulmin, 1964), their petrography will not be reviewed here. A brief statement of the history of emplacement and crystallization of the "alkalic" rock suite may, however, not be out of place. The following is quoted with minor modification from the author's unpublished thesis*

[1]Publication authorized by the Director U.S. Geological Survey

*Toulmin, Priestley, III, 1958, Bedrock geology of the Salem area, Massachusetts: Ph.D. Thesis, Harvard University, Cambridge Massachusetts

Granitic magma, probably somewhat poorer in SiO_2 than the Peabody Granite and typical Cape Ann Granite is believed to be the source magma of the leucocratic rocks of the "alkalic" series The diversity of the leucocratic rocks is attributed to differentiation processes in essentially the same place where the rocks are now found, rather than in some hidden magmatic chamber at greater depth. The over-all form of the major intrusive body, the Cape Ann pluton, is not known, but at least local portions of its contact dip inward.

Crystallization of the magma began with the separation of alkali feldspar comparatively rich in Or (at least Or_{61}). In the interior of the pluton crystallization apparently continued uninterrupted and sufficiently slowly to allow more or less complete reaction between feldspar crystals and liquid, for zoned feldspar crystals are rare in the granites. During crystallization the feldspar became richer in Ab, but in none of the granites did the feldspar become less potassic than about Or_{44} Quartz and ferrohornblende probably began to crystallize at about the same time the order of their appearance may have differed from place to place within the crystallizing magma.

On the margin of the pluton a porphyritic facies was developed which grades continuously inward into granite both by increase in the proportion of phenocrysts and by appearance of phenocrysts of quartz and hornblende in addition to the feldspar phenocrysts present in the outermost shell.

Where volcanic activity occurred, the crystallization of the underlying magma was affected, principally by loss of H_2O. Rapid crystallization of feldspar ensued, and the feldspar so formed is nearly all between Or_{25} and Or_{40}, very much poorer in Or than the feldspars formed in the interior of the pluton. Where a "floor" of country rock existed under such a shower of sodic feldspar crystals, the crystals accumulated to form masses of syenite, passing upward into granite as "normal" crystallization resumed.

The many mafic dikes associated with the leucocratic rocks were formed at almost the same time as the leucocratic rocks; evidence of overlapping and almost contemporaneous intrusion is abundant. Some genetic relationship presumably exists between the mafic and granitic magmas, but whether they have differentiated from a common ancestor or are more or less independent products of the same general process of magma generation is unknown At any rate, there is little doubt that both existed as mechanically separate magmas before they moved to the level of the crust now exposed in the Salem area.

The textures of many of the trachytic syenite dikes imply that they have crystallized from a liquid of essentially the same composition as that of the rock The most likely source of such a liquid is the fusion of

massive syenite; the composition of the feldspar of the trachytic syenite is compatible with such an origin. The source of the heat required is uncertain, but mafic dikes in the area are known to have fused their syenitic wall rocks, and a larger body of mafic magma "at depth" presumably would be capable of fusing a larger body of syenite. Many of the rocks of the contact zone on Salem Neck and Great Misery Island may represent various stages of fusion and reaction of mafic and leucocratic rocks.

The intrusion of the granitic magma was probably not a simple single event. The rocks mapped as Cape Ann Granite in the Salem area are variable in composition and texture, but some areas in the interior of the Cape Ann pluton (mostly outside the Salem area) resemble the Peabody Granite both in compositional uniformity and in the rarity or absence of younger mafic dikes. These facts suggest that at some time after the intrusion (and differentiation?) of the Cape Ann pluton, granitic magma again invaded the area to form the Peabody stock and the areas of uniform granite within the Cape Ann pluton. Variations of the granites of the Cape Ann pluton have not been studied systematically in the present investigation; detailed study of the whole pluton should answer many of the questions left unanswered here.

ROAD LOG

Mileage	Notes
0.0	South Lynnfield Interchange(intersection of routes U.S. 1 and Mass. 128). Head east (toward Gloucester) on Route 128.
1.6	Peabody Industrial Development Commission on right.
2.0	The little quarry just off the road to the left is Stop 1, but it is necessary to continue a short distance and make a U turn to reach the quarry.
2.6	Make permitted U turn.
3.2	Stop 1.

STOP 1. This stop exhibits the typical aspect of the Peabody Granite. The rock is a medium-coarse-grained granite composed of quartz, microperthite, ferrohornblende, and accessories. As seen in this quarry and elsewhere throughout the Peabody stock, it is quite homogeneous both in composition and in structure. Xenoliths are fairly sparse in most outcrops, and widely spaced joints are characteristic. No flow structure is evident in the interior

of the stock though some may be observed near the contacts. Aplite and porphyritic microgranite dikes are common, but trap dikes are very rare in the Peabody Granite.

Mileage	Notes
0.0	On leaving Stop 1 it is necessary to go west a short distance and then make another U turn across the center strip to go east on Mass. 128
0.1	Make permitted U turn.
1.1	Stop light at Forest Street. Continue on Route 128.
1.4	Cross contact between Peabody Granite to SW and Salem Gabbro-Diorite to NE. The granite underlies the relatively higher area through which you have just come. The gabbro-diorite in general occupies a lower area ahead; possibly the ridge of gabbro-diorite directly ahead is held up because of increased resistance somehow related to the contact of the younger granite stock.
2.4	Take Exit 25N. Mass. Route 114 toward Middleton and North Andover.
2.9	Pass North Shore Shopping Center on left.
3.2	Continue straight on Route 114.
3.8	Danvers town line. The high ground to the left is underlain by Peabody Granite; the lowland to the right is underlain by Salem Gabbro-Diorite.
4.6	Railroad underpass.
5.0	Turn right onto U.S. 1, following signs for Newburyport N.H. and Maine.
5.8	Turn right into interchange at Dayton Street following sign for Danvers. Stop 2.

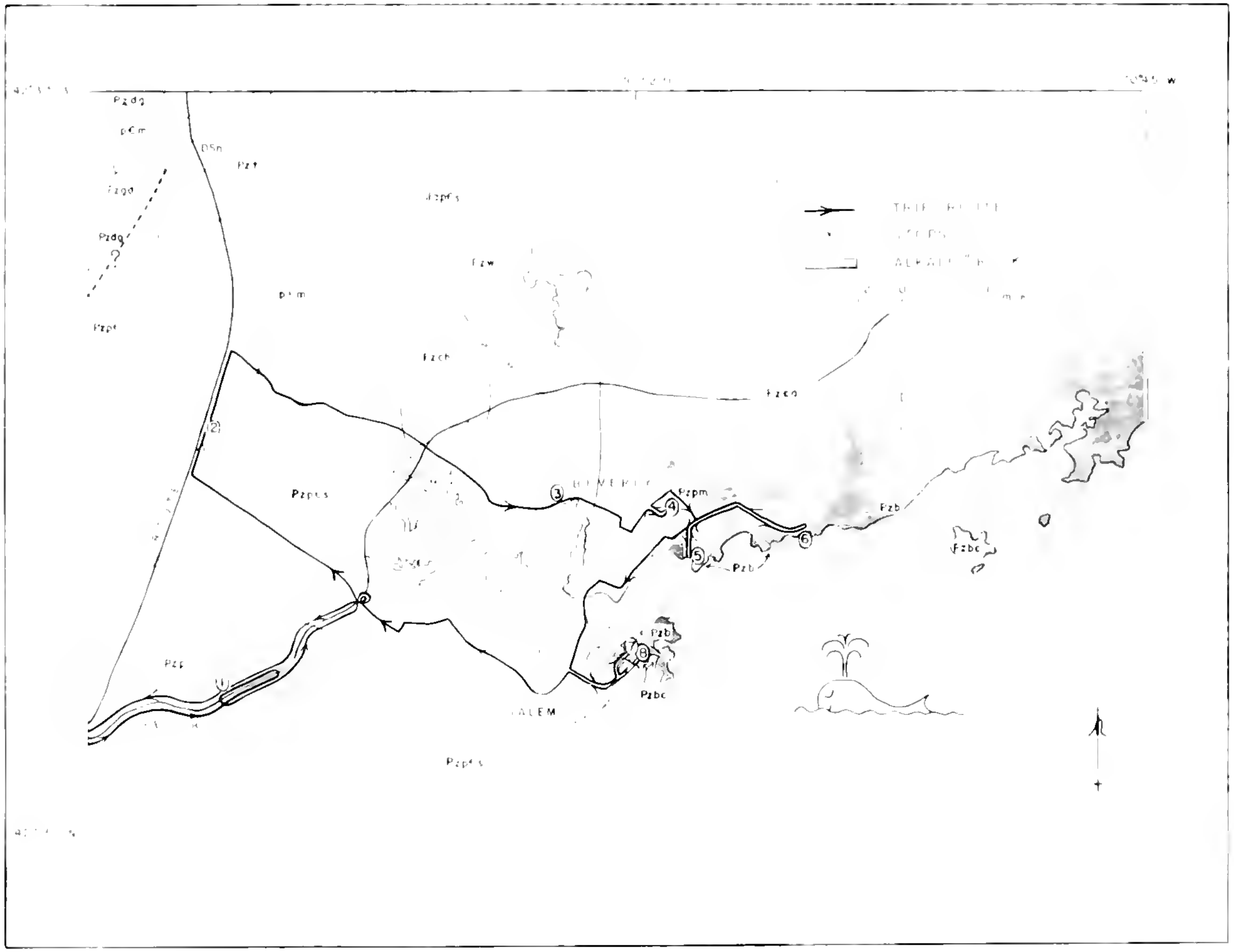

Figure 1. Sketch map of route of trip Sat. E. Rock units: Pzb, Beverly Syenite; Pzbc, Beverly Syenite contact zone; Pzw, Wenham Monzonite; Pzpm, porphyritic microgranite; Pzch, Cherry Hill Granite; Pzca, Cape Ann Granite; Pzp, Peabody Granite; Pzt, Topsfield Granodiorite; Pzgd, medium-grained granodiorite; Pzdg, diorite and gabbro, undifferentiated; DSn, Newbury Formation; PzpGn, Newburyport(?) Quartz Diorite; PzpGs, Salem Gabbro-Diorite; pGm, Marlboro(?) Formation. Geology after Toulmin (1958, 1960, 1964).

STOP 2. The rocks exposed in the road cuts of the interchange here are fairly typical of the dominant lithologies in the Marlboro (?) Formation in the Salem quadrangle. The plagioclase amphibolite ranges from a distinctly foliated to an apparently isotropic fabric. The augen gneiss displays a considerable range in megacryst content and in degree of foliation.

The structural details of the locality are complex. A small fold in the augen gneiss (in the cut on the west side of the first ramp east of U.S. 1 and north of the road passing under U.S. 1) apparently resulted from the wrapping of the gneiss around the blunt end of a plagioclase-amphibolite layer, which may have pulled apart during deformation (though its continuation has not been identified). The areas of different foliation attitudes north and south of the road passing under U.S. 1 here may be separated by a minor fault, for the rocks at the west end of this road are altered.

Mileage	Notes
0.0	Leave Stop 2, heading north on U.S. 1
0.7	The buildings on the left, on top of the prominent drumlin you are crossing, are the Danvers State Hospital.
1.0	Turn right on Mass. Route 62 toward Beverly.
1.3	Bear right at stop sign.
2.1	Bear left on Route 62.
2.4	Cross Beaver Brook.
2.8	Bear left on Route 62.
3.0	Stop light at Locust Street. Continue on Route 62.
3.6	Bear right on Route 62 at stop light.
3.9	Continue straight under Route 128 on Route 62. The drumlin on the left just beyond Route 128 is Folly Hill, capped by a water reservoir for the city of Salem.
4.8	Bear left on Route 62 at fork in road.

5.7 Stop 3. Park by store right of road.

STOP 3. The rocks along the left side of the road here are more or less typical of the Salem Gabbro-Diorite near its contact with younger intrusives of the "alkalic" igneous complex. The rock has been somewhat recrystallized locally, and is shot through with veins or small dikes of more salic materials, which may be either highly contaminated alkalic rock or the product of selective refusion of the gabbro-diorite.

Mileage	Notes
0.0	Leave Stop 3, going east (toward Beverly) on Mass. 62.
0.7	Continue across Mass. Route 1-A on Route 62.
0.8	Turn right on Route 62 at Cabot Street; take second left turn, still following signs for Route 62
1.1	Turn left (north) on Mass. Route 22 (Essex Street). The hill on the playground to the right is the locality for the amazonite described and analyzed by J.W. Webster in 1824.
1.5	Turn right on Cedar Street (unpaved). The outcrop across Essex Street from Cedar Street is Cape Ann Granite.
1.7	Turn left into quarry. Stop 4.

STOP 4. The principal rock of this little quarry is a porphyritic microgranite so crowded with phenocrysts that at first glance it could be mistaken for an equigranular syenitic rock. At the extreme southeast end of the outcrop, there is an area of similar rock in which round quartz phenocrysts are prominent, giving the rock a granitic aspect. The most interesting features in the quarry, however, are those associated with the mafic dikes that cut through the porphyritic microgranite in the central and northwestern part of the quarry.

The large outcrop just south of the center of the northeast edge of the quarry shows a nearly flat-lying mafic dike about 8-10 inches thick that extends along almost the entire outcrop. Near the center of the outcrop, this dike is offset both perpendicular and parallel to its walls in such a way as to suggest irresistibly that the dike has been broken and pulled apart and that the surrounding rock must have been able to flow easily

enough to fill in the resulting potential void Careful scrutiny fails to reveal fractures that could have served as faults to produce the observed relations. Although the heat-supply problem is admittedly a difficult one, no better solution has occurred to the writer than to suggest that a still warm vitrophyre might fracture allowing the intrusion of an andesitic magma with a liquidus temperature sufficiently higher than that of the vitrophyre so that the observable chilled borders of the dike could result: the vitrophyre, though brittle enough to fracture under short-term stresses, might react viscously to more slowly applied, long-continued forces, so that the flowage required to explain the separation of the two parts of the dike could have taken place. The chilled margins of the dike are clearly transected by the ends of the two segments of the dike, so the relations cannot be explained as the result of an originally branched intrusion

Similar tearing apart of trap dikes seems to have taken place in the porphyritic microgranite of the northwestern outcrop in the quarry, but apparently at a time when the wall rocks were at least slightly cooler and less yielding Here the spaces between the matching dike segments are occupied by quartz-rich pegmatite or pods of quartz. These were presumably sweated out of the country rocks.

Both phenomena strongly suggest that the mafic dikes were emplaced quite shortly after the emplacement of the porphyritic microgranite, which implies the simultaneous presence in near proximity of magmas of strongly contrasting composition

Mileage	Notes
	Leave Stop 4 and retrace route to intersection of Cedar and Essex Streets.
0 0	Intersection of Cedar and Essex Streets. Turn right (north) on Route 22 (Essex St.).
0.4	Turn right on Corning Street, just past Plummer's Store.
0.9	Stop sign Continue straight.
1.1	Turn right on Hale Street (Mass. Route 127) at stop sign
1 2	Turn left on Woodbury Street.
1 5	Stop at dead-end at water. Stop 5

STOP 5. The outcrops on the shore here are fairly typical of the Beverly Syenite. The feautres to be noted particularly are the range in grain size and the large size of some of the microperthite crystals. The outcrop should be visited at low tide.

Mileage	Notes
0.0	Leave Stop 5, retracing route along Woodbury Street.
0.3	Turn right on Mass. 127 (Hale Street).
0.4	Cross Corning Street. Church In The Cove on right. Continue on Hale Street (Mass. 127).
1.0	Make sharp right turn at blinking yellow light, still following Mass. 127.
1.6	Main entrance to Endicott Junior College on left (College Hall and others). Continue on Route 127.
1.9	Mingo (Endicott) Beach on right. Stop 6. Please remember that we are on College property here.

STOP 6. The outcrops at water's edge on the east side of the point in the middle of Mingo Beach show a portion of the contact between Beverly Syenite and Peabody Granite. The relations are, unfortunately not so clear-cut here as in some other localities, which are not accessible to a group the size of this one, but the generally continuous, or abruptly transitional, character of the contact can be seen. In some localities in West Manchester, the contact is practically unmarked structurally, but consists simply of a surface across which the quartz content of the rock increases abruptly in an otherwise continuous mesh of crystals of the other minerals, chiefly feldspar. At the present stop, an aplite dike follows much of the contact, but the general relations may be discerned.

Syenite, which makes up most of the seaside exposures on the headland, acquires minor amounts of quartz over an interval of about 20 feet toward the contact with granite in the easternmost outcrop (next to the beach). Granite underlies the northwestern part of the point and the hilly area across Hale Street to the north; the syenite on the point is one of several remnants of a body that probably once was a continuous band of syenite south of the granite.

Mileage	Notes
0.0	Leave Stop 6, heading west (toward Beverly and Salem) on Mass 127.
0.9	Turn sharp left at blinking yellow light; stay on Mass 127
1.5	Cross Corning Street (Church In The Cove on left), continue straight on Mass 127
1.9	Bear left on Route 127.
2.0	Intersection with Route 62, turn left on Route 127
2.8	Turn right, following Route 127
3.1	Turn left following Route 127, which here merges with Mass. 22; at mile 3.2, these merge with Mass 1-A Follow any and/or all of these toward Salem.
3.4	Turn left across bridge on Mass. 1-A.
3.7	South end of Danvers River Bridge Continue south on Route 1-A.
4.3	Turn left on Webb Street (watch closely for this turn)
4.5	Bear right: follow road along end of Collins Cove.
4.7	Cross Essex Street; bear left around traffic island shortly thereafter.
5.0	Intersection with Derby Street, Fort Avenue, and Memorial Drive, by fire house and power plant. Turn left on Memorial Drive (left of fire house) and continue on Memorial Drive
5.4	Stop at power line. Stop 7 is outcrop behind house at 64 Memorial Drive (on right).

STOP 7. The rock at this stop is an exceptionally fine example of a type that is quite widespread in the area of Salem Neck mapped as "Beverly Syenite contact zone" in USGS Bull. 1163-A; the rock consists of a mixture of mafic porphyry and leucocratic syenite, arranged in a fashion at least geometrically similar to the basalt and palagonite of pillow lava. Both rocks show evidence of contamination -- labradorite phenocrysts of the dark porphyry have albitic centers, and crystals of the minerals of the dark porphyry are strewn through the syenite. The ellipsoidal structure is widespread but is particularly well displayed in this outcrop, where it also shows the unusual feature of apparently having been deformed more or less synchronously with its formation. The crudely synclinal structure in the outcrop is obvious; if the near-vertical fractures in the axial region are tension fractures related to the deformation that produced the syncline, then the fact that syenite fills them implies that the syenite is either younger than, or more or less synchronous with the folding. Inasmuch as the ellipsoidal structure has not been seen without the syenite stringers between the ellipsoids, it seems reasonable to assume that the origin of this structure and the syenite are closely related; hence the syenite must be essentially contemporaneous with the folding.

Mileage	Notes
0.0	Leaving Stop 7, retrace route along Memorial Drive.
0.2	Continue straight: do not bear right past hospital, but go left of Bentley School.
0.4	Intersection at fire house and power plant; turn left on Fort Avenue.
0.8	Park on right at gate at near (SW) end of stone wall. Go through gate and follow path to shore of Cat Cove. This is Stop 8.

STOP 8. This stop displays both the wide variety of rock types in the Beverly Syenite contact zone and several interesting igneous structures. Dikes of many varieties of porphyry cut one another in considerable confusion. The youngest dike rock is the nepheline-sodalite syenite, a blue-gray rock in which a greasy-looking feldspathoid is apparent in hand specimen. What looks like a single mineral is actually both nepheline and a sodalite that fluoresces bright orange in long-wavelength ultraviolet light; it is virtually identical to the mineral described from the nepheline-sodalite syenite of Red Hill, N.H. (Quinn, 1935, 1937). At various places along the shore of the cove, one can see good examples of ellipsoidal structure

and discontinuous dikes that may result either from an initial branching of the fracture along which the dike was emplaced or from later deformation. At the extreme western end of the outcrop by the masonry wall near the wire fence that surrounds the sewage plant, is an outcrop of coarse-grained fresh gabbro. this rock which was referred to by Washington (1898-1899) as the "hyperitic variety" of essexite, is composed of fresh labradorite. olivine, augite, hornblende, and biotite for the most part without any textural indication of a reaction relationship. Alkali feldspar is very rare, and nepheline absent, as noted by Washington.

Mileage	Notes
0.0	Leaving Stop 8, retrace route along Fort Avenue.
0 4	Bear right at fire house and power plant (do not make sharp right turn into Memorial Drive)
0 7	Continue straight across Essex Street on Webb Street
0 9	Bear slightly left at McManus Square.
1.0	Turn left on Routes 107 and 114.
1 1	Bear slightly right at flashing yellow light, following signs for Mass. 107, <u>not</u> for Mass. 1-A.
1.5	Go right around rotary, then branch right, following signs for Mass. 114.
2.0	Bear slightly left, following Route 114.
2.5	Cemetery entrance on right.
3 0	Route 114 turns left; follow it.
3.5	Stop light Turn left, following Route 114.
3.6	Take second right, following signs for Route 114.
4 3	Pass over Route 128: turn right on ramp to Route 128 toward U.S. 1, following signs for S. Lynnfield and Boston.

5.9	Forest Street stop light.
6.7	Quarry of Stop 1 on right.
7.9	Turnoff to U.S. 1 and South Lynnfield Interchange.

TRIP E

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TRIP F

THE MARLBORO FORMATION IN THE CONCORD QUADRANGLE[1]

Norman P. Cuppels, U.S. Geological Survey

In describing the great variety of lithologic units which he included in the Marlboro Formation of Precambrian(?) age, Emerson (1917, p. 31) indicated that the "formation may eventually be broken up into several formations". Emerson's observations on the lithologic heterogeneity of the Marlboro are supported by recent mapping in the Concord quadrangle by the writer. Preliminary results of this mapping are shown on the geologic map accompanying this road log. The purpose of this field trip is to examine the variety and complexity of some of the lithologic units mentioned by Emerson and mapped by the writer.

All stops on this field trip are in the $7\frac{1}{2}$ minute Concord quadrangle except Stop 1. Stop 1 is in the Marlboro quadrangle. The trip will be repeated in an abbreviated form on Sunday at which time Stops 1, 4, and 6 will be omitted.

Log starting from campus of Boston College:

Miles	
00.0	West on Commonwealth Ave. at Main Gate.
5.7	Charles River. The river is very close to the western boundary of the Boston Basin. The Cambridge Slate (Devonian or Carboniferous) crops out east of the river and the Dedham Granodiorite of Devonian(?) age is exposed west of the river. Cross the river and onto Rte. 128 headed north.
7.9	Left on Rte. 20 to Marlboro.
24.7	Stop 1.

STOP 1 - Outcrops are along right side of Rte. 20 and in cemetery 200 feet up the hill on the north side of the road.

This is the type locality of the Marlboro Formation (Emerson, 1917, p. 25-26). Emerson describes the Marlboro in this area as a well-foliated, dull-black biotite schist intercalated with many beds of dark, well-foliated hornblende schist, and a few beds of conglomerate and quartz-epidote rock. Small, slightly elongate pebbles of aplite in the conglomerate contain much plagioclase and have a micrographic texture. Elsewhere in northeastern Massachusetts, the Marlboro, as mapped by Emerson (1917, p. 31), includes "... a

[1] Publication authorized by the Director, U.S. Geological Survey.

variety of rock, although green, gray and black chloritic, hornblendic, epidotic and biotitic schists predominate. Interbedded with these are many thin layers of quartzite and quartz-muscovite schist and in places, of rhyolite, and the formation also includes a number of small bodies of limestone and a few lenses of conglomerate". In some places, the quartzite and rhyolite are very abundant and were thought by Emerson to constitute the upper part of the formation or a separate and younger formation.

Emerson mapped two arcuate belts of Marlboro extending 30 miles northeastward from the Marlboro quadrangle. These belts, each of which is about one mile wide, coalesce in the Concord quadrangle. Within the belts, the formation is exposed in the form of many small outcrops surrounded by and included in igneous rocks of Paleozoic age.

Miles	
	Reverse direction on Rte. 20.
35.7	Left on Rte. 126.
36.7	Cross southern boundary of Concord quadrangle.
41.4	Right on Baker Bridge Road.
44.3	Right on Sandy Pond Road.
44.4	Left at entrance to DeCordova Museum.
44.8	Stop 2.

STOP 2 - Outcrop is along road west of museum. Bus will use museum parking lot east of museum. Map unit 2: thin-bedded amphibolite.

The amphibolite exposed here is considered to be correlative with the amphibolite at the type area of the Marlboro Formation. The rock is chiefly actinolitic hornblende and plagioclase with varied amounts of quartz, epidote, and biotite. The conglomerate seen at the type locality occurs in places along the strike of this unit. The lithologic units shown on the geologic map are numbered in the order of increasing age and will be visited in that order as nearly as possible. Possible discrepancies in the age sequence will be discussed during the trip.

Miles	
	Leave museum grounds and turn right on Sandy Pond Road
45.5	Stop 3.

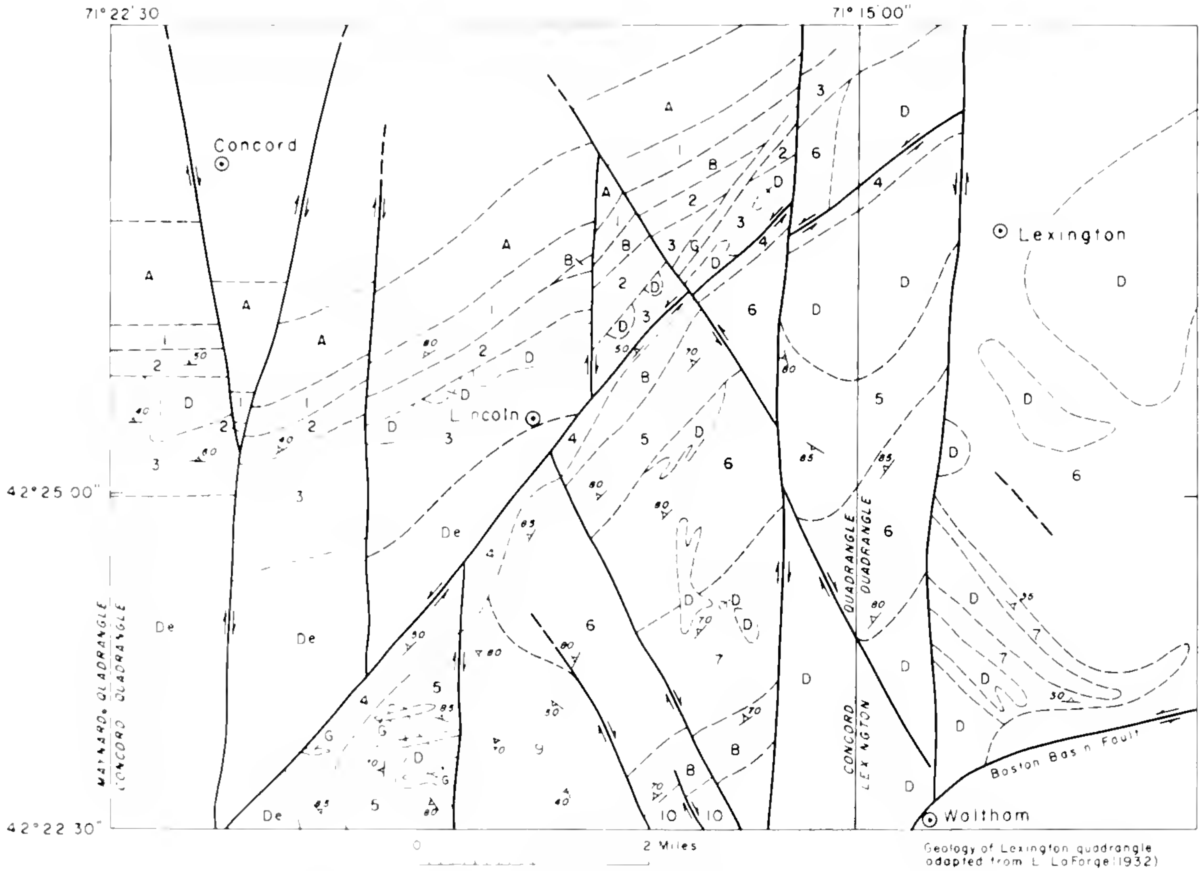

Figure 1 Simplified geologic map of the Marlboro Formation in parts of the Concord and Lexington quadrangles

EXPLANATION

Metasedimentary Rocks

1	Nashoba Formation	Carboniferous
	Marlboro Formation	Precambrian(?)
2	Amphibolite, thin-bedded	
3	Quartzo-feldspathic schist, with lenses of marble	
4	Felsite, laminated	
5	Paragneiss, thin-bedded	
6	Amphibolite, thick-bedded	
7	Quartz-feldspar granulite	
8	Quartz-hornblende-plagioclase schist	
9	Amphibolite, lineated	
10	Westboro Quartzite	Precambrian(?)

Intrusive Rocks

A	Andover Granite	Carboniferous
G	Granite	Carboniferous(?)
B	Diabase	Upper Paleozoic(?)
De	Dedham Granodiorite	Devonian(?)
D	Diorite	Lower Paleozoic(?)

Symbols

Strike and dip of foliation

Strike and dip of foliation and parallel bedding

Fault, showing relative movement

Lithologic boundary

STOP 3 - Outcrops are in a field on right side of road. Poison ivy is abundant near these outcrops. Map unit 1: Nashoba Formation

The quartz-mica schist exposed here is not typical of the Nashoba Formation as described by Hansen (1956, p. 31-39). Because of its mineralogy and texture however, it more properly belongs with the high-alumina Nashoba Formation than with the finer grained low-alumina Marlboro Formation. It may correlate with the Brimfield Schist. This is the closest outcrop to the contact between the two formations.

Miles	
	Reverse direction on Sandy Pond Road
45.0	Right on Baker Bridge Road
47.2	Left on Concord Road (Rte. 126).
48.6	Right on Rte. 117.
50.0	Cross Sudbury River and turn right into private driveway
	Stop 4.

STOP 4 - Outcrops are near intersection of driveway and Rte. 117, and in back yard of residence. Map unit 3: quartzo-feldspathic schist with lenses of marble. The metasedimentary rocks crop out peripherally to a diorite dike.

The lithology of this schist is much more varied than the amphibolite of Stop 2. In general it is a strongly bedded and foliated unit and consists of thin beds of quartz-plagioclase-chlorite schist, interbedded with plagioclase amphibolite and impure thin- to thick-bedded marble. At this locality, nodules of copper-iron-sulfide are common.

Miles	
	Reverse direction on Rte. 117.
52.5	Hatheway School of Conservation Education operated by the Audubon Society.
53.2	Cross a major fault zone
53.4	Right on Tower Road (Coburn Road on topographic sheet)
53.5	Stop 5

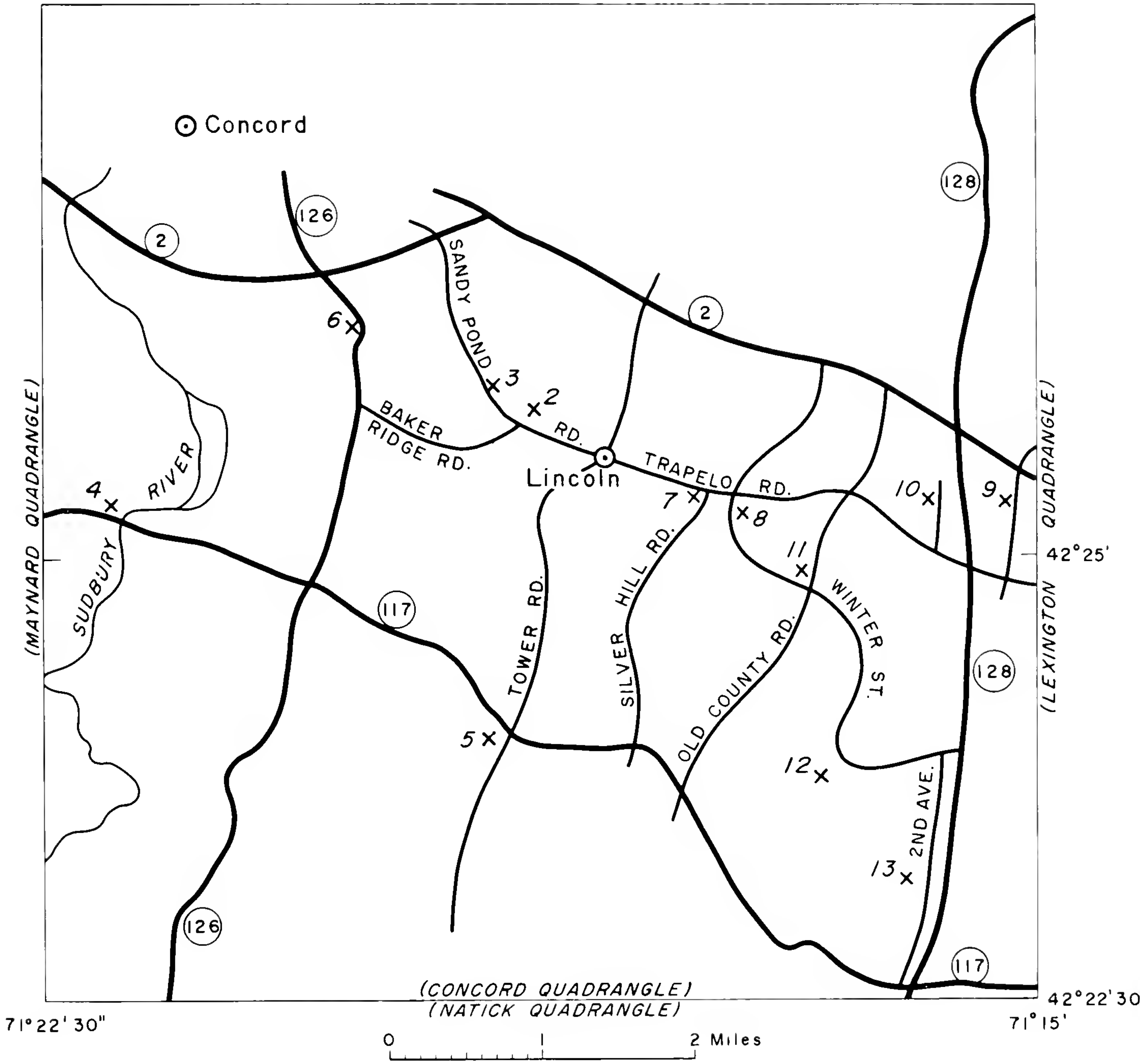

Figure 2. Location of stops for field trip No. 6

STOP 5 - Outcrop is along railroad tracks west of Tower Road. Map unit 4: Laminated felsite.

This felsite is a very fine-grained, light-gray to light-green to light-brown, quartzo-feldspathic rock characterized by pronounced laminae. Locally it grades into a rock resembling a sheared granite with conspicuous "leaves" of quartz. At some places, the laminae are continuous across the outcrop; elsewhere, the laminae appear to be fractured and rotated, as at this stop. The laminae seem to be the result of a weak development of compositional layering in which quartz-rich layers alternate with layers rich in plagioclase and some chlorite. The plagioclase is partly sericitized.

Miles	
	Reverse direction on Tower Road.
53.7	Left on Rte. 117.
55.8	Right on Rte. 126.
57.8	Stop 6.

STOP 6 - Lunch Stop. - Walden Pond - The pond is a kettle in delta deposits of glacial Lake Sudbury. Thoreau (1893, p. 285-286) cites an Indian legend which describes the disappearance of a hill that formerly occupied the present site of Walden Pond.

One hour has been allocated for lunch.

Miles	
	Reverse direction on Rte. 126.
58.5	Left on Baker Bridge Road.
59.8	Right on Sandy Pond Road.
60.4	Lincoln Center. Straight ahead to Trapelo Road.
61.1	Right into driveway of private residence.
	Stop 7.

STOP 7 - Outcrop is in the back yard of the property owner. Rock here is map unit 4, laminated felsite.

The felsite at this stop appears to be gradational between the felsite seen at Stop 5 and a rock resembling a sheared granite.

Miles

Return to Trapelo Road and turn right.

61.4 Right on Winter Street. First house on left

61.8 Stop 8

STOP 8 - Exposure is a recently dynamited outcrop of thin-bedded paragneiss, map unit 5, in a field 200 feet east of Winter Street.

This paragneiss is characterized by compositional layers that are more continuous than any other lithologic unit in the quadrangle. A bed of feldspathic quartzite less than 10 feet thick has been traced in this unit for more than a mile. Most of the layers are considered to be metasedimentary beds, and consist of hornblende-plagioclase-quartz schist, feldspathic quartzite, plagioclase amphibolite, quartzo-feldspathic granulite, hornblende-epidote-zoisite schist, and sills of granite.

Miles

Return to Winter Street Right on Winter Street to Trapelo Road

61.5 Right on Trapelo Road.

64.2 Left on Smith Street at traffic light.

64.8 Stop 9 In yard of house with big red barn.

STOP 9 - Outcrop of thin-bedded paragneiss, map unit 5, is near summit of Fuller Hill on southeast side

The outcrops in this area are more amphibolitic than the rocks of unit 5 seen at Stop 8. White, quartzo-feldspathic layers 4 inches to 18 inches thick are thought to be metamorphosed silicic tuff

Miles

Reverse direction on Smith Street

65.4 Right on Trapelo Road at traffic light.

65.9 Right on Brennan Avenue.

66.3 Stop 10

STOP 10 - Outcrops are in a recent excavation along east side of hill fault zone

Rocks exposed at this stop are in one of the major north-trending fault zones of the Concord quadrangle The rocks are thoroughly shattered, and highly polished slickensides of epidote are abundant in the thick-bedded amphibolite (Unit 6), gabbro, diabase, and granite. Evidence can be seen for the following sequence of events from oldest to youngest:

1 Faulting of the thick-bedded amphibolite
2 Intrusion of the gabbro and diabase.
3 Faulting of the amphibolite, gabbro, and diabase
4 Intrusion of the granite.
5 Faulting of the entire complex.

Miles	
	Reverse direction on Brennan Avenue.
66.7	Right on Trapelo Road.
67.4	Left on Old County Road.
68.4	Right on Winter Street.
68.7	Stop 11.

STOP 11 - Thick-bedded amphibolite, map unit 6, exposed in a road cut along right side of Winter Street

This is a good exposure of the thick-bedded amphibolite. It is composed chiefly of actinolitic hornblende and heavily saussuritized plagioclase. Light-colored megacrysts, which occur in some zones, are composed of sericitized plagioclase and quartz

Miles	
	Reverse direction on Winter Street.
70.5	Right on private road to Casala's piggery.
71.3	Stop 12

STOP 12 - Outcrops are in an abandoned pig sty. Map unit 7, quartz-feldspar granulite.

Map unit 7 is a white, to light brown, aphanitic to fine-grained weakly foliated, quartzo-feldspathic rock Varietal minerals include diopside, garnet hornblende, biotite, epidote, and zoisite. Much of the unit appears to have a clastic texture. Emerson excluded this unit from the Marlboro Formation, mapping it as a "gneiss and schist of unknown age".

Miles	
	Return to Winter Street.
72.1	Right on Winter Street
73.0	Right on Second Avenue. This road not shown on topographic sheets.
74.1	Stop 13

STOP 13 - Outcrops are on right side of road in excavation, exposing unit 8, quartz-hornblende-plagioclase schist

This unit is a thin-bedded to laminated, light-green to gray schist that commonly weathers white. At some places, much of the hornblende is altered to epidote and zoisite.

TRIP F

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GEOLOGY OF THE NORFOLK BASIN CARBONIFEROUS SEDIMENTARY ROCKS, AND THE VARIOUS IGNEOUS ROCKS OF THE NORWOOD AND BLUE HILLS QUADRANGLES[1]

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Most of the important rock units between the Boston basin on the north an the Narragansett basin on the south will be seen on this trip. Road cuts made in recent years, particularly along Routes 24 and 128, provide excellent new exposures of many of the units.

The Blue Hill Granite Porphyry and associated rocks have been of much interest ever since the publication of the classic memoir of W.O. Crosby in 1900 and the important petrographic work of Charles Warren published in 1913. New information concerning this complex has been accumulating from field work and age dating.

The Norfolk basin sedimentary rocks also have attracted considerable attention in this area, particularly the giant conglomerate of the Pondville Conglomerate. The new exposures at the interchange of Routes 28 and 128 show the basal contact of this boulder conglomerate and are of special interest.

List of rock units

Igneous rocks

Triassic	Diabase dikes
Devonian and/or Carboniferous	Diabase dikes Blue Hill Granite Porphyry Quincy Granite Fine-grained hornblende granite Mattapan Volcanic Complex and aporhyolite
Devonian (?)	Rhombenporphyry and Sharon Syenite Diabase sills (in the Braintree Argillite) Fine-grained biotite granite Dedham Granodiorite Newburyport Quartz Diorite Salem Gabbro-Diorite

Sedimentary Rocks

[1] Publication authorized by Director, U.S. Geological Survey

Pennsylvanian	Wamsutta Formation Pondville Conglomerate
Cambrian	Braintree Argillite
	Metamorphic Rocks
Precambrian	Marlboro(?) Formation

Review of the Bedrock Geology

Rock Units

Marlboro(?) Formation

Fine-grained amphibolite resembling some of the Marlboro Formation is closely associated with the Salem Gabbro-Diorite in the central and southern parts of the Blue Hills quadrangle. This rock, which will be seen at Stops 10 and 11, has been variously recrystallized and injected by younger intrusives. One of its most characteristic features is the usual presence of irregular dioritic stringers with gradational boundaries that may be of metamorphic origin. Recrystallization has reduced the grain size of the amphibolite adjacent to the stringers, and felsic elements may have migrated into the stringers from the recrystallized rock nearby.

Salem Gabbro-Diorite, Newburyport Quartz Diorite, Dedham Granodiorite, and fine-grained biotite granite.

The Salem Gabbro-Diorite, Newburyport Quartz Diorite, Dedham Granodiorite, and fine-grained biotite granite, listed in order of age from the oldest to youngest, constitute a magma series of widespread distribution in eastern Massachusetts.

The Salem Gabbro-Diorite and the Newburyport Quartz Diorite are closely related in age, but the quartz diorite forms separate small bodies and in places can be seen to intrude the Salem. The calcic plagioclase of the Newburyport and the Salem have been altered to epidote, sericite, and albite by the late Paleozoic regional metamorphism, and these rocks no longer have their original mineral composition. The Newburyport can be distinguished by its numerous equidimensional grains of hornblende about $\frac{1}{4}$ inch in diameter. The Salem, on the other hand, always has slender unoriented hornblende prisms that, except in the pegmatitic pods, are less than $\frac{1}{4}$ inch in length.

The Dedham Granodiorite and the fine-grained biotite granite have intruded the Salem Gabbro-Diorite extensively, and hybrid rocks have formed near the

contacts by assimilation. Such a hybrid variety of the fine-grained biotite granite is widespread in the northwest corner of the Norwood quadrangle.

Recent Rb-Sr whole rock age determinations (Ramo and Fairbairn, 1963, p. 53) were made on a sample of the fine-grained biotite granite from the central part of the Blue Hills quadrangle and on one from the interchange of Routes 109 and 128. These were classed as Dedham by authors following Emerson (1917). The ages determined are 573 m.y. and 562 m.y., respectively. Another sample from North Abington gave an age of 684 m.y. The rock from which this sample came contains inclusions of mafic rock, large pink potash feldspar phenocrysts, and 5-10% chloritized biotite. It appears to be somewhat contaminated by the mafic rock, and it may be a contact phase of the Dedham Granodiorite.

The Dedham Granodiorite is a pinkish-gray, medium- to coarse-grained rock composed of abundant quartz, plagioclase ranging from albite to andesine, and potash feldspar. The plagioclase, more calcic than sodic oligoclase, has been largely destroyed by regional metamorphism. A small amount of chloritized biotite is the only ferromagnesian mineral.

The fine-grained biotite granite, formerly grouped with the Dedham Granodiorite, has been mapped by the writer as a separate formation. It is distinguished from the Dedham by its distinctly finer texture, and its younger age. The normal granite contains potash feldspar, albite, quartz, and a small amount of chloritized biotite. Phases of this granite include a hybrid variety formed by assimilation of mafic rocks, a pink variety formed by hydrothermal alteration of the normal granite, and a porphyritic variety.

Braintree Argillite

The Braintree Argillite of Middle Cambrian age is seen at Stop 14 where it has been recrystallized to fine-grained black hornfels. No fossils have been found in this area. Thin bedding, which strikes nearly east-west and dips steeply southward, is distinguishable in most places. The numerous diabase sills in the Braintree appear to be truncated by a large crosscutting apophysis of Quincy Granite. Most of the pre-Triassic diabase dikes are considered to be Carboniferous and are younger than the granite.

Sharon Syenite and Rhombenporphyry

Sharon Syenite and related small bodies of diorite, fine-grained granite, and aplite form a pluton several miles long in the southern part of the Norwood quadrangle and the northern part of the Mansfield quadrangle to the south. Small bodies of the syenite that grade into the rhombenporphyry have been found in the Blue Hills quadrangle. Both rocks are composed primarily of microperthite

and soda orthoclase. Augite is the chief mafic mineral. Most of the phenocrysts of the rhombenporphyry are rhombic-shaped microperthite crystals.

The Sharon Syenite is known to be younger than the Salem Gabbro-Diorite and the rhombenporphyry to be older than the Quincy Granite. Xenoliths of rhombenporphyry are common in the Quincy. The rhombenporphyry and the syenite are higher in lime and alumina than the rocks of the Blue Hills and may not belong to this complex as has been previously thought.

Mattapan Volcanic Complex and Aporhyolite

The Mattapan Volcanic Complex is widespread in the northwestern part of the Norwood quadrangle and will be seen at Stops 4, 5, 6, and 7. In this quadrangle it consists of felsite flows, pyroclastics, small felsite porphyry intrusions, and felsite dikes. LaForge (1932, p. 35) considered the Mattapan to be an effusive phase of the Quincy Granite.

The name "aporhyolite" (devitrified rhyolite) has long been applied to similar volcanic rocks in the Blue Hills area which probably also belong to the Mattapan Complex. The aporhyolite, like the Mattapan Complex elsewhere, contains considerable fragmental material and has structures ascribed to ash-flow tuffs. The volcanic rocks have been devitrified, and the relative amounts of flow and fragmental material is difficult to determine.

The largest area of aporhyolite is at the eastern end of the Blue Hills Range between Great Cedar Swamp and Pine Hill. The aporhyolite has been impreganted by pyrite near a fault zone that extends northeast from Great Pond along the west side of Pine Hill. Because of this, the road cuts along Route 128 northeast of Great Cedar Swamp are heavily limonite stained.

Bottino (1963, p. 65) obtained whole-rock Rb-Sr ages of 248 $\pm$ 10 m.y. for the aporhyolite, 245 $\pm$ 10 m.y. for the Blue Hill Granite Porphyry, and 345 $\pm$ 15 m.y. for the Quincy Granite. Numerous xenoliths of the aporhyolite in the porphyry indicate that the former is older than the latter. Also, well-developed chilled contacts in the Quincy Granite against the aporhyolite exposed in the road cuts on the east side of Pine Hill suggest that the aporhyolite is older than the Quincy in that area.

Quincy Granite and Blue Hill Granite Porphyry

The Quincy Granite forms an east-west pluton about 10 miles long, and the Blue Hill Granite Porphyry forms the high hills of the Blue Hills Range along the south side of the western half of the granite pluton. Both the Quincy

Granite and the Blue Hill Granite Porphyry are alkalic rocks characterized by low alumina, lime and magnesia, and the presence of microperthite, riebeckite, and aegirite.

The Blue Hill Granite Porphyry has generally been considered to be a chilled contact phase of the Quincy Granite. Bottino's (1963, p. 65) age determinations, however, suggest that the granite is older than the porphyry. Recent field observations by the writer indicate that the Blue Hill Granite Porphyry is a separate intrusion and is younger than the Quincy Granite. Irregular bodies of Quincy Granite in the Blue Hill Granite Porphyry, formerly regarded as dikes of granite cutting the porphyry, are now believed to be xenoliths.

Pondville Conglomerate and Wamsutta Formation

The Norfolk basin is a faulted syncline of Carboniferous nonmarine sedimentary rocks. It extends northeastward across the southern part of the Norwood quadrangle and for 4 miles along the south side of the Blue Hills to Great Pond in the Blue Hills quadrangle. Its average width in these quadrangles is about $1\frac{1}{2}$ miles.

In this area the Pondville Conglomerate ranges from about 500 to 1500 feet in thickness. It has been divided into a lower coarse conglomerate member and an upper medium to fine conglomerate and coarse sandstone member. The most common types of rock in the conglomerate are felsite from the Mattapan Volcanic Complex, Dedham Granodiorite, and quartzite. The boulders of the giant conglomerate, which is limited to the central part of the Blue Hills quadrangle, are nearly all fine-grained hornblende granite. With them are some pebbles and cobbles of Blue Hill Granite Porphyry and other rock types.

The contact between the Pondville and the overlying Wamsutta is gradational. As seen at Stop 12, the gray conglomerate of the upper member of the Pondville is interbedded with red Wamsutta type sandstone near the contact. The contact is placed where the amount of red beds first exceeds the gray beds.

The Roxbury Conglomerate of the Boston basin is only $2\frac{1}{2}$ miles from the Norfolk basin in the northern part of the Norwood quadrangle, suggesting that the basins at one time may have been connected. The Norfolk basin connects with the Narragansett basin and both contain the Pondville and Wamsutta Formations. Correlation with the Boston basin, however, is not as clear and has remained uncertain. The writer believes that the basins are essentially contemporaneous and that the Pondville Conglomerate and the Wamsutta Formation of the Norfolk basin correlate respectively with the Brookline Conglomerate and

[illegible] that Members of the Roxbury Conglomerate in the Boston basin. The Brookline Conglomerate Member closely resembles the Pondville Conglomerate in lithology and thickness, and the Dorchester Member and the Wamsutta Formation also are similar. Both the Dorchester Slate Member and the Wamsutta Formation are composed of red, purple, and green slates and sandstones, with some interbedded gray fine conglomerate.

Diabase Dikes

Diabase dikes and sills of different ages are present in the Norwood and Blue Hills quadrangles. The sills in the Braintree Slate are pre-Carboniferous, whereas most of the predeformation dikes are considered to be Carboniferous. The intersecting dikes of different ages at Stop 2, however, show that they are not all exactly the same age.

The predeformation diabase dikes were strongly altered by the late Paleozoic metamorphism to epidote, chlorite, sericite, and albite, and their original mineral composition is uncertain. The greenish alteration minerals give these dikes a greenish-gray color and cause them to resist weathering better than the unaltered Triassic diabase dikes.

The diabase dikes that are younger than the late Paleozoic metamorphism are generally considered to be Triassic. They form a north-south dike system and are essentially unaltered, in marked contrast to the predeformation dikes which are thoroughly altered. In places, as at Stop 1, they can be seen to cut the predeformation dikes and can be distinguished by their black color on fresh surfaces and their brown color on weathered surfaces. They often show columnar structure, which, together with their mineral composition, causes them to weather more rapidly than the predeformation dikes.

Structural Geology

The rocks of the Norwood and Blue Hills quadrangles were faulted and folded during the late Paleozoic orogeny. Several large strike-slip faults cut the Norfolk basin, and thrust faults border the basin. Most of the faults are concealed and are inferred, but the rocks near them are considerably fractured and altered. The rocks along the fault zone that extends northeast from Great Pond along the valley on the west side of Pine Hill in the northeast part of the Blue Hills quadrangle were impregnated by pyrite. Similar mineralization borders the Stony Brook fualt in the Neponset River valley of the Norwood quadrangle.

Regional Metamorphism

The late Paleozoic diastrophism caused low-grade metamorphism of the greenschist facies in this area. Epidote and chlorite are present nearly everywhere in the igneous rocks, both within the rocks and coating joints and shear fractures. Mafic rocks with calcic plagioclase, such as the predeformation diabase dikes, were greatly altered. The calcic plagioclase was altered to epidote, calcite, sericite, and albite. The hornblende and biotite were at least partly chloritized. Hematite was developed from the primary ferromagnesian minerals coloring the rocks pink or red in places.

The oldest rock in the area, the Marlboro(?) Formation, is largely amphibolite variously altered. It indicates an older metamorphism of the amphibolite facies.

Itinerary

The itinerary begins at Boston College in the west-central part of the Boston basin of Carboniferous sedimentary rocks. Most of the bedrock mapped by LaForge (1932) in this area is Roxbury Conglomerate, the basal formation of the Boston Bay Group. Basaltic flows, sills, and dikes of the Brighton Melaphyre occur within the Roxbury Conglomerate. Exposures of the Roxbury Conglomerate and the Brighton Melaphyre will be seen along the route south to Stop 1.

Miles	Total Miles	
	0	Start at south entrance to Boston College on Beacon Street. Turn right (W) on Beacon Street.
0.2	0.2	Turn left (SE) on Hammond Street.
0.8	1.0	Roxbury Conglomerate both sides of road.
0.1	1.1	Cross Route 9.
0.25	1.35	Roxbury Conglomerate on right.
0.2	1.55	Brighton Melaphyre on both sides of road at intersection with Woodland Road.
0.2	1.75	Brighton Melaphyre on right.
0.1	1.85	Brighton Melaphyre on left for next tenth of a mile.
0.15	2.0	Traffic circle on the Hammond Pond Parkway.

Miles	Total Miles	
0.05	2.05	Continue southeast on parkway.
0.1	2.15	Small exposure of Roxbury Conglomerate or fragmental volcanics in median on left.
0.05	2.20	Cross an E - W thrust fault that forms the south boundary of the Brighton Melaphyre area.
0.4	2.6	Roxbury Conglomerate on both sides of road at top of hill.
0.1	2.7	Roxbury Conglomerate on right
0.15	2.85	Enter traffic circle at intersection with Grove Street.
0.05	2.9	Leave traffic circle on the West Roxbury Parkway.
0.2	3.1	Roxbury Conglomerate on left.
0.35	3.45	Turn right (W) on Route 1.
0.5	3.95	Roxbury Conglomerate on left on west side of Shell gasoline station.
0.3	4.25	Roxbury Conglomerate on right.
1.85	6.10	Turn right (SW) on Route 109. Leave the Boston basin and enter area of crystalline rocks.
05	6.15	Cross the Charles River which here is the boundary between the City of Boston and the Town of Dedham.
1.25	7.4	Recross the Charles River.
0.20	7.6	Intersection with Common Street at traffic light. The center of the village of Dedham is a short distance left
0.25	7.85	Leave the Newton quadrangle and enter the Norwood quadrangle
0.7	8.55	Stop 1 - Park on right side of Route 109 near the exit road

Miles	Total Miles	
		to the NW-bound lanes of Route 128. The large road cut near Route 109 is Salem Gabbro-Diorite and fine-grained biotite granite variously modified by assimilation and metamorphism. Three Triassic and several older diabase dikes are well exposed here. The Triassic dikes cut the older dikes and are readily distinguished by their brown weathered color and lack of alteration. The older dikes are greenish gray because of alteration to chlorite, epidote, and albite.
		The next exposures, a few hundred feet to the northwest, are pink fine-grained biotite granite. Formerly this granite was included with the Dedham Granodiorite. The fine-grained biotite granite is normally light gray, and the pink color here is a result of hydrothermal alteration. Formerly this pink granite was quarried for dimension stone and used in buildings and walls in Boston and Dedham. Two of the pink granite quarries were filled and obliterated when the interchange at the intersection of Routes 109 and 128 was constructed.
		The pink granite is cut by a number of parallel flat-dipping pre-Triassic diabase dikes that occupy a well-defined set of joints. A younger vertical pre-Triassic diabase dike can be seen to cut a flat-dipping dike in this part of the interchange. Continue southwest on Route 109 to the first road right, just beyond the interchange.
0.55	9.1	Turn right on road to Westfield Street. Road cuts to next turn are in Salem Gabbro-Diorite and fine-grained biotite granite.
0.15	9.25	Turn sharp right into short dead-end street.
0.5	9.75	Stop 2 - Park at end of road and cross fence to south end of large road cut on the west side of the exit road from the SE-bound lanes of Route 128. This cut is mostly Salem Gabbro-Diorite and Newburyport Quartz

Miles	Total Miles	
		Diorite. Fine-grained biotite granite and aplite intrude these rocks at both ends of the cut.
		Proceed northward along the cut and note the intrusion breccia formed by the fine-grained biotite granite; irregular pods of segregation pegmatite in the Salem Gabbro-Diorite and other textural variations in this rock; intersection of two pre-Triassic diabase dikes near the bottom of the cut, one with a very low dip and the other vertical; and the Newburyport Quartz Diorite. The Salem Gabbro-Diorite can be distinguished from the Newburyport Quartz Diorite by the presence of slender unoriented hornblende prisms in the former and larger nearly round poikilitic hornblende grains in the latter. Continue north on the road to Westfield Street.
0.5	10.25	Turn right (N) on road to Westfield and continue past Grove Street.
0.5	10.75	Exposure of intrusion breccia of fine-grained biotite granite on left. Small exposures of Salem Gabbro-Diorite, fine-grained biotite granite, and intrusion breccia for the next 0.2 mile.
0.35	11.10	Stop 3 - Road cuts on left in intrusion breccia of the fine-grained biotite granite with fragments of Newburyport Quartz Diorite, Salem Gabbro-Diorite, and Marlboro(?) Formation for about 200 feet to bend in road at north boundary of the Norwood quadrangle. At the north end of the road cut is a 12-foot felsite dike of the Mattapan Volcanic Complex cut by a pre-Triassic diabase dike. The felsite dike has spherulitic structure near its center and marginal flow banding.
		Return to Route 109.
0.6	11.70	Turn right (SW) on Route 109 and continue through the village of Westwood.
2.3	14.0	Volcanic breccia on right.

Miles	Total Miles	
0.1	14.1	<u>Stop 4</u> - Exposure of volcanic breccia of the Mattapan Volcanic Complex on the right (NW) side of Route 109 (High Street) opposite the end of Lake Shore Drive. Several small areas of volcanic breccia of varying coarseness are present in the Mattapan Volcanic Complex to the north and west. Most of the fragments of the breccia are felsite from the Mattapan and the Dedham Granodiorite.
		Continue southwest on Route 109. Exposures of volcanic breccia on the right for 0.3 mile.
0.6	14.7	<u>Stop 5</u> - Gray to lavender felsite exposed on the right along the sidewalk a short distance southwest of Mill Street. Except for the presence of distinct flow banding, this rock is representative of the most common type of rhyolite in the Mattapan of this area.
		Continue southwest on Route 109.
0.15	14.85	<u>Stop 6</u> - Fragmental Mattapan including ash-flow tuffs(?) exposed about 100 feet up the slope on the northwest side of the road. Considerable variation is shown in the coarseness and structural features of different layers of the volcanic rock at this exposure and others higher on the hill to the north.
		Continue southwest on Route 109.
0.2	15.05	Turn right (N) at Burgess Avenue.
0.25	15.3	Exposure of the Mattapan on left.
0.6	15.9	Turn right (NE) at Hartford Street.
0.15	16.05	Road cut on left in massive gray porphyritic rhyolite that weathers pink. Several small bodies of this rock, which may be intrusive, occur in this area.
0.45	16.5	Outcrops of the Mattapan in woods on right.

Miles	Total Miles	
0.8	17.3	Junction with Route 109. Turn left (N) and proceed through Westwood to Route 128.
1.5	18.8	Turn right at interchange to southeast-bound lanes of Route 128.
0.4	19.2	Road cut on right in fine-grained biotite granite.
0.2	19.4	Road cut on right in fine-grained biotite granite cut by Triassic and pre-Triassic diabase dikes.
0.2	19.6	Fine-grained biotite granite in roadcut.
0.2	19.8	Road cuts to Route 1 overpass are Dedham Granodiorite with a few diabase and rhyolite dikes.
0.65	20.45	Route 1 overpass.
0.4	20.85	Hold right onto ramp for interchange at East Street, and go half way around the interchange.
0.45	21.3	Turn right onto East Street.
0.95	22.25	Turn right (E) onto Sprague Street at traffic circle.
0.4	22.65	Turn right (SW) on Stoughton Road.
0.1	22.75	Stop 7 - Large outcrop of Dedham Granodiorite on the right side of Stoughton Road near Nobel Road. Usually good exposures of erosion remnants of a rhyolite dike or flow of the Mattapan Volcanic Complex can be seen on the west side of the outcrop behind the houses on Nobel Street. The rhyolite is flow banded and contains a few inclusions of the Dedham.

Two small basic dikes cut the Dedham but not the rhyolite in the northern part of the exposure. This is one of the few places where pre-Carboniferous basic dikes can be recognized.

Miles	Total Miles	
		The prominent outcrop of Dedham Granodiorite at the corner of Stoughton and Nobel Roads also is examined at this stop. This outcrop illustrates the regional greenschist metamorphism that accompanied the Appalachian orogeny late in the Paleozoic and resulted in widespread development of chlorite, epidote, albite, and sericite, particularly in the mafic rocks.
		A pre-Triassic diabase dike 2 feet wide is exposed at the edge of the sidewalk at the northwest end of the outcrop.
		Turn right on Nobel Road and return to Route 128.
0.15	22.9	Turn left (NW) at Sprague Street.
0.35	23.25	Turn left (SW) at traffic circle and continue on East Street.
0.95	24.2	Interchange at Route 128. Proceed around the interchange and exit to the southeast-bound lanes of Route 128.
0.4	24.6	Exposures of fine-grained biotite granite on right side of ramp to 128.
0.3	24.9	Salem Gabbro-Diorite in road cut on right. Several small exposures of Salem Gabbro-Diorite and Mattapan Volcanic Complex on the right and left for the next 0.2 mile.
0.7	25.6	Quartzite and phyllite of the Green Lodge Formation of Rhodes and Graves (1931) of Cambrian age in hill to right.
0.4	26.0	Bridge over the New York, New Haven, and Hartford RR. The Stony Brook tear fault of the Boston basin underlies the Neponset River valley in this vicinity and offsets the Norfolk basin to the south.
0.15	26.15	Bridge over the Neponset River. Borings at this bridge and the railroad bridge show the presence of a buried valley with a floor about 100 feet below sea level. This buried valley approximately follows the Neponset River.

Miles	Total Miles	
0.8	26.95	West edge of a glacial-lake delta deposited by a stream that flowed westward. Route 128 crosses the delta to near its intersection with Route 138.
0.35	27.3	Leave the Norwood quadrangle and enter the Blue Hills quadrangle. Great Blue Hill, the highest hill (summit altitude 635 feet) of the Blue Hills Range can be seen ahead on the left. The Blue Hills meteorological observatory and broadcasting installations are at the top of the hill. The ledges visible on the side of the hill are Blue Hill Granite Porphyry.
0.3	27.6	Route 138 overpass.
0.35	27.95	Pondville Conglomerate on left.
0.2	28.15	Pondville Conglomerate on right.
0.25	28.4	Large cuts in the upper part of the Pondville Conglomerate on right and left.
0.25	28.65	Turn right to bridge to Houghton's Pond.
0.15	28.8	Turn left (NW) on bridge.
0.55	29.35	Turn right (E) at Hillside Street.
0.3	29.65	Turn right into Houghton's Pond parking area.
0.1	29.75	Stop 8 - Lunch Stop at Houghton's Pond (called Hoosicwhisick Pond on the topographic map).
0.1	29.85	Leave parking lot and turn left on Hillside Street.
0.4	30.25	Turn left at road to Route 128.
0.55	30.8	Turn left (E) at end of bridge to east-bound lanes of Route 128.
0.45	31.25	Road cut in red sandstone of the Wamsutta Formation on right.

Miles	Total Miles	
0.15	31.4	Turn right (S) on Route 24.
0.1	31.5	Wamsutta red sandstone on right.
0.05	31.55	Stop 9 - Large road cut in unfossiliferous sandstone and slate of the Wamsutta Formation. About 300 feet of the lower part of the Wamsutta Formation is exposed in this road cut providing an unusually good opportunity to observe the interesting lithologic and structural features. Most of the exposure is reddish sandstone with crossbedding, ripple marks, cut-and-fill structures, and mudcracked shale partings. Dark red and maroon slate beds and a few gray, fine conglomerate beds occur at intervals in the section. The beds strike N. 75° to 85° E. and dip south. The dip flattens southward in the exposure toward the axis of the syncline. The slaty cleavage has the same strike as the beds but dips 60° to 80° N., indicating that the syncline is overturned toward the south. Continue south on Route 24.
1.15	32.7	Bridge over cross street.
0.1	32.8	Approximate location of the E - W thrust fault (upthrown on the south) inferred to bound the Norfolk basin on the south. The bedrock south of the fault to the south boundary of the Blue Hills quadrangle consists of the Marlboro(?) Formation, Salem Gabbro-Diorite, Newburyport Quartz Diorite, Dedham Granodiorite, and the fine-grained biotite granite.
1.0	33.8	Road cuts at Canton town line in Marlboro(?) Formation, Salem Gabbro-Diorite, and Newburyport Quartz Diorite. (This will be Stop 11).
0.65	34.45	Road cut on right in Salem Gabbro-Diorite at north edge of interchange.

Miles	Total Miles	
0.3	34.75	Turn right at interchange to bridge over Route 128.
0.5	35.25	Turn right on east side of interchange to northbound lanes of Route 24.
0.1	35.35	Fine-grained biotite granite on left.
0.05	35.4	Stop 10 - Salem Gabbro-Diorite and Marlboro(?) Formation on right. Walk along the road cut to Route 24. The Marlboro(?) here is fine-grained dark-green amphibolite with dioritic stringers of possible metamorphic origin such as occur in part of the Marlboro near the type locality. Later irregular granite stringers and a small pegmatite from the fine-grained biotite granite cut both the Marlboro(?) and the Salem Gabbro-Diorite. Continue to Route 24 and proceed north.
0.15	35.55	Route 24.
0.6	36.15	Salem Gabbro-Diorite on right.
0.05	36.2	Small knob of Salem Gabbro-Diorite on right with unusual textural variations.
0.3	36.5	Stop 11 - Large road cut in Marlboro(?) Formation, Salem Gabbro-Diorite, and Newburyport Quartz Diorite cut by a large feldspar porphyry dike that dips flatly northward. This exposure provides an unusually good opportunity to observe the relationships of these various rock units, and the aplite and pegmatitic stringers that cut them. A particular feature is the pseudo-chilled boundaries of the Marlboro(?) amphibolitic rock with the dioritic stringers. Recrystallization of the Marlboro(?) near the stringers has caused a reduction in grain size, imitating chilled contacts. Along with the recrystallization, some of the felsic constituents of the rock may have migrated into the stringers. Continue north to the eastbound lanes of Route 24.

Miles	Total Miles	
1.0	37.5	Cross the inferred boundary fault and re-enter the Carboniferous Norfolk basin. The route crosses the Wamsutta Formation from here to Route 128.
0.75	38.25	Red Wamsutta sandstone on right.
0.25	38.5	Hold right to eastbound lanes of Route 128.
0.2	38.7	Wamsutta sandstone on left.
0.2	38.9	Enter Route 128 east.
0.3	39.2	Turn right (S) at the Route 28 interchange toward Randolph.
0.05	39.25	<u>Stop 12</u> - Road cut on right exposes the contact between the Pondville Conglomerate and the overlying red Wamsutta Formation. The contact is gradational and is placed where the amount of red sandstone and slate first exceeds the gray Pondville type coarse sandstone and conglomerate. The bottom contact of the Pondville is exposed on the north side of the interchange (Stop 13). Continue southward toward Route 28.
0.4	39.65	Turn around and proceed north on Route 28 to the north part of the interchange.
0.4	40.05	Turn right at north part of interchange to the west-bound lanes of Route 128.
0.4	40.45	Turn right to the southbound lanes of Route 28. Giant Pondville Conglomerate in road cuts near Route 128. The rest of the cuts to Route 28 are Blue Hill Granite Porphyry.
0.25	40.7	Junction with southbound lanes of Route 28. Proceed under first bridge, turn right on old road, and park.

Miles	Total Miles	
0.05	40.75	Stop 13 - Giant Pondville Conglomerate. Walk west along the old road and observe the exposures of the giant conglomerate. About 500 feet from Route 28, on the left (S) side of the road next to the small stream, is an exposure of granule and pebble conglomerate of the upper part of the Pondville. This exposure has two well-developed potholes, one 4 feet in diameter. Return to Route 28 and walk north under the bridge and up the bank to the large exposure of giant conglomerate on the north side of Route 128. The conglomerate in this area contains numerous unusually large boulders some of which are as much as 4 feet in length. Most of the large boulders are fine-grained hornblende granite, possibly the fine-grained granite associated with the Quincy Granite. A variety of rock types make up the pebbles and cobbles including Cambrian(?) quartzite, Cambrian Braintree(?) Argillite, felsite, and Blue Hill Granite Porphyry. No Quincy Granite has been observed. The conglomerate can be seen to rest unconformably on Blue Hill Granite Porphyry. The contact strikes about east - west and dips steeply south, as the conglomerate here is on the north limb of the Norfolk basin syncline. The Blue Hill Granite Porphyry was weathered for 50 feet or more below the base of the conglomerate before the conglomerate was deposited. A residual soil zone about 9 feet thick is underlain by a zone of spheroidal weathering with pseudocobbles and boulders. Chlorite, epidote, and hematite were developed in the conglomerate and the porphyry probably during the late Paleozoic regional metamorphism. Return to the parking place and proceed around the southern part of the interchange to go north on Route 28.
0.1	40.85	Turn right (W) to Route 128 eastbound.

Miles	Total Miles	
0.4	41.25	Turn right (S) to northbound lanes of Route 28.
0.3	41.55	Route 28, continue north.
1.35	42.9	Blue Hill Granite Porphyry and aporhyolite on right ("aporhyolite" is an old term used in this area for devitrified rhyolite).
0.05	42.95	Intersection with Chickatawbut Road at traffic light, continue north.
0.8	43.75	Outcrop of a large diabase dike on right. For the next 0.4 mile the route crosses an east - west belt of the Braintree Argillite of Cambrian age, but no exposures are visible from the road.
0.35	44.1	Stop 14 - Braintree Argillite, diabase dikes, rhombenporphyry, and Quincy Granite. Turn right into gravel road and park. Walk about 425 feet along the road from Route 28 and climb up the hillside on the left to observe the outcrop of Braintree. Continu eastward to the top of the hill and observe the outcrops.

This hill has numerous exposures of the Braintree Argillite of Cambrian age, now metamorphosed to black fine-grained hornfels. Thin bedding is distinguishable; it strikes nearly east - west and dips steeply south. An unusual feature here is the presence of a large number of diabase sills in the Braintree that appear to be older than the Quincy Granite.

An apophysis of Quincy Granite with abundant inclusions of rhombenporphyry and a few of the Braintree cuts across the Cambrian rocks from north to south. This apophysis, which is over 100 feet in width, appears to be younger than the diabase sills and to cut them off.

On the top of the hill to the northeast are exposures of Quincy Granite with a border zone of

Miles	Total Miles	
		intrusion breccia where it is in contact with the rhomberporphyry. As usual, the rhombenporphyry shows marked variations in the abundance of feldspar phenocrysts. In places the phenocrysts are so abundant that the rock is syenite identical with the Sharon Syenite. A good exposure of this syenite can be seen a short distance east of the old house foundation on the top of the hill
		Return to the parking place and proceed south to Chickatawbut Road.
1.15	45.25	Turn left (E) on Chickatawbut Road. This road is on the north side of the main range of the Blue Hills.
0.5	45.75	Parking place and picnic area on the north side of Chickatawbut Hill with observation tower and access to trails.
0.6	46.35	Blue Hill Granite Porphyry in road cut on left. The crocidolite variety of riebeckite coats the joints. Blue Hills Reservoir on right.
0 35	46.7	<u>Stop 15</u> - Blue Hill Granite Porphyry and aporhyolite on the right.
		Follow the trail up the rock knob from the small parking area. Midway up the knob is a band of aporhyolite bounded on both sides by Blue Hill Granite Porphyry. The contact can be observed on the south side of the band. The porphyry at the top of the knob contains long shreds of aporhyolite which are xenoliths that were deformed plastically. A striking pseudo-breccia has been produced in the porphyry by hydrothermal alteration, especially near the aporhyolite.
		Walk east several hundred feet to the next large knob of Blue Hill Granite Porphyry and continue to adjacent knobs of aporhyolite on the east and southeast. This aporhyolite has many of the charac-

Miles	Total Miles	
		teristics of ash-flow tuffs. One of the problems w the aporphyolite in the Blue Hills area is distinguish ing flows, ash-flow tuffs, and ash-fall tuffs
		Return to the parking place and continue east or Chickatawbut Road.
0.05	46.75	Turn left on Wampatuck Road, aporhyolite on left
0.25	47.0	Aporhyolite on right at bend in road.
0.65	47.65	A knob of diabase, called Babel Rock, on left
0.45	48.1	Turn left on Willard Street.
0.05	48.15	Turn right into interchange and proceed under the Southeast Expressway to the opposite side of the interchange.
0.25	48.4	Take first right off the interchange
0.05	48.45	Turn right (E) onto Miller Street at Gulf station
0.1	48.55	Large outcrop of weathered Quincy Granite on left at junction of streets.
0.05	48.6	Turn right on Centre Street.
0.6	49.2	Turn right on Vernon Street at the sign for the Old Colony Crushed Stone Company.
0.2	49.4	Entrance to quarry area.
		<u>Stop 16</u> - Old Colony Crushed Stone Company's Quarry. This quarry has been worked for many yea and provides good exposures of Quincy Granite, rhombenporphyry, fine-grained hornblende granite associated with the Quincy Granite, and diabase dikes. The rhombenporphyry and fine granite are exposed on the west side of the quarry but be-

cause of extensive faulting and shearing the rock relations are obscure. Pink Quincy Granite and sheared pre-Triassic diabase dikes are exposed on the north side of the quarry.

The south side of the quarry, which is now being worked, is Quincy Granite cut by a few diabase dikes. Near the southwestern corner of the quarry the granite has numerous inclusions of rhombenporphyry, again illustrating the tendency of the granite to form intrusion breccia where it is in contact with this rock.

The normal gray Quincy Granite and the pink Quincy Granite are well exposed in the eastern and central parts of the main south quarry face. The pink granite has formed along sets of steeply inclined joints by hydrothermal alteration of the gray granite. The primary ferromagnesian minerals of the granite have been destroyed and hematite formed. A halo of chloritized gray granite borders the pink granite bodies. A diabase dike 20 feet wide, believed to be Triassic, also has strongly chloritized granite adjacent to it on both sides for about 20 feet from the dike.

Dark blue crocidolite coats some of the joint surface of the normal gray granite. The pink alteration destroyed the crocidolite and in the chloritized margins chlorite coats the joints.

TRIP G

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STRUCTURE AND STRATIGRAPHY OF THE NANTASKET LOCALITY[1]

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The field trip to the Nantasket locality will show some structural features of the southeast margin of the Boston Basin and some of the stratigraphic detail of a sequence of interlayered sedimentary and volcanic rocks that is a part of the Boston Bay Group. The sedimentary rocks are composed mainly of volcanic detritus of local origin.

General Features

The terrain in the vicinity of Nantasket is within the Seaboard Lowland section of the New England physiographic province as described by Fenneman (1938). The bedrock surface is a peneplane dissected by narrow, shallow stream valleys; it is rough and hummocky in minor detail but has no conspicuous hills. The land slopes almost imperceptibly toward the coast Many small islands and submerged reefs and ledges indicate that the gentle slope continues under the ocean. The terrain is characterized by numerous low, almost bare rock knobs and ridges between which is a thin mantle of glacial drift and soil and many small marshes and swamps. Northwest of Nantasket Beach are several drumlins connected by sand plains, bars. and beaches devoid of outcrops.

Structure

The Nantasket locality is on the south margin of the Boston Basin which is a depressed part of the Seaboard Lowland Here the margin of the basin is a fault zone at least 2 miles wide trending approximately N. 70° E. The major faults strike northeast to east have displacements of tens of feet to possibly a few hundred feet; the downthrown sides are to the north. Between major faults are multitudes of anastomosing faults having northeast to southeast strikes, steep to vertical dips, and displacements of a few inches to a few tens of feet, with the downthrown sides in most instances on the north

A few faults trending generally north-south and having nearly vertical dips and displacements of a few feet to possibly a few tens of feet probably formed concurrently with compressional folding of the Boston Basin.

The south part of Hull and the northeast part of Hingham, areas that include all the outcrops of the Boston Bay Group in the Nantasket locality, form

[1] Publication authorized by the Director U.S. Geological Survey

a northeast-plunging syncline. Complex faulting and lenticular strata preclude precise estimation of plunge, but it is probably between 10° and 20°. Successively younger units of the Boston Bay Group are exposed from west to east along the axis of the syncline.

Bedrock Geology

The rocks in the Nantasket locality are granodiorite and associated aplite that Emerson (1917) included with the Dedham Granodiorite; volcanic and sedimentary rocks of the Boston Bay Group; and several kinds of dikes. All these rocks are nonfossiliferous, and they are not associated with fossiliferous rocks in other localities. In the vicinity of Nantasket, conglomerates within the Boston Bay Group contain felsite boulders that almost certainly came from the Lynn Volcanic Complex. In other localities conglomerates within the Boston Bay Group contain boulders eroded from the Mattapan Volcanic Complex. These volcanic rocks generally are considered to have been erupted during the middle part of the Paleozoic era. The Boston Bay Group seems to have been deposited shortly after eruption of the Lynn and Mattapan volcanic rocks. An erosional unconformity separates the Boston Bay Group and the older granodiorite. Most of the dikes in the Nantasket locality were emplaced during the volcanism that produced the volcanic rocks in the Boston Bay Group. A few dikes seem to be younger and may be among those generally thought to be of Triassic age.

The granodiorite is predominantly a medium- to coarse-grained granitic-textured rock, but in places it is porphyritic. Quartz, microcline, and plagioclase generally constitute at least 90 percent of the rock, though the proportions of the major constituents vary considerably. Aggregates of chlorite, epidote, and hornblende seem to be remnants and products of partial deuteric alteration of original mafic constituents. Plagioclase generally is saussuritized, in places only slightly, and elsewhere so much that twinning features are almost obscured. Pale pink aplite is abundant and in places occurs as large irregular dikelike masses. Xenoliths of older rocks can be seen at several places. Xenoliths in the cliffs along the Cohasset shore, east of Nantasket Beach, are rather fine-grained amphibolites those in the vicinity of Little Harbor, Cohasset, and Strawberry Point, Scituate, are diorite.

The Boston Bay Group consists of interlayered agglomerates, andesites, tuffs, tuffaceous shales, and conglomerates. These rocks were laid down in quick succession, in part, at least, in a subaqueous environment. The principal source of volcanic material was an explosive volcano east or northeast of the Nantasket locality. The sedimentary rocks are predominantly agglomerates; tuffs and tuffaceous shales generally occur as thin beds, and conglomerates composed of wave-worn cobbles and boulders occur infrequently. The thickness of various units changes considerably within short distances, and some units

are small lenticular deposits. This circumstance, combined with intricate faulting that causes repetition and cutting out of units in several places, makes stratigraphic correlation difficult and uncertain.

The basal unit of the Boston Bay Group in the Nantasket locality is a coarse mixture of agglomerate and conglomerate. It rests upon a rough granodiorite surface and contains considerable arkose and boulders from the underlying rock. Much of the volcanic detritus is more silicic than the local andesites, indicating origin from older flows and from terrain some distance away.

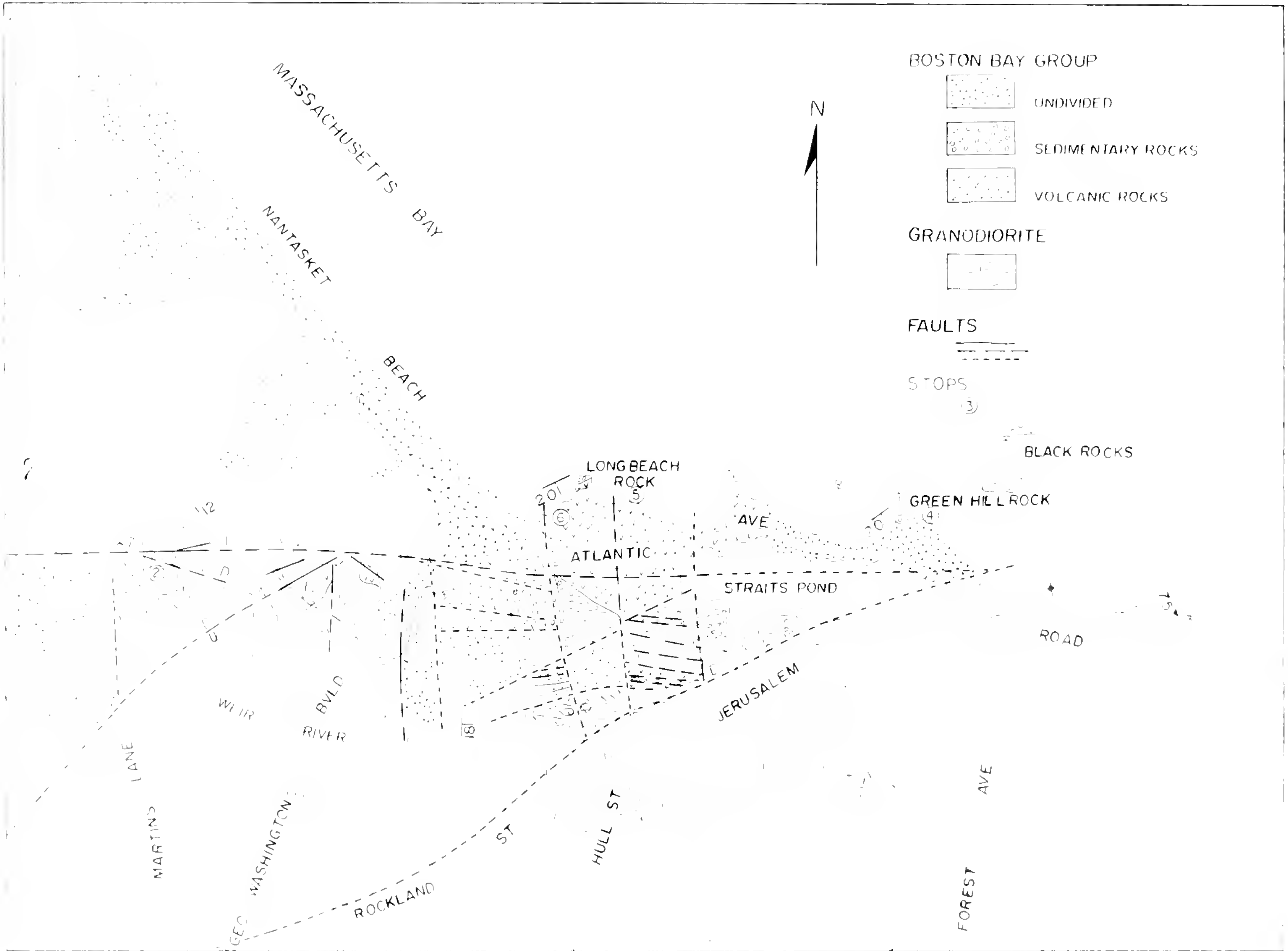
Agglomerates higher in the group are composed mainly of volcanic debris having virtually the same composition as enclosing flows and lesser quantities of the silicic volcanic rocks, and granodiorite.

The Nantasket volcanic rocks are altered andesites. The flows were erupted from local vents, and some of them apparently covered only small parts of the area. The alteration was deuteric and probably was modified by action of sea water upon the lavas. Plagioclase, chlorite, and epidote are the major constituents of these rocks, and magnetite is the principal minor constituent. Most of the rocks contain no primary quartz, but quartz and calcite may be rather abundant secondary constituents. There are four groups of flows: 1) highly-altered, dark-greenish-gray flows that rest upon the basal agglomerate and are exposed only in the western part of the locality; 2) light-greenish-gray to dark-reddish-gray porphyries composed mainly of small plagioclase phenocrysts in a groundmass of plagioclase microlites and iron oxides; these rocks are exposed in cliffs southwest of the amusement park, Green Hill Rock and the larger of the Black Rocks; 3) dark-greenish-gray to reddish-gray, partly amygdaloidal flows that are considerably altered; these flows are exposed between George Washington Boulevard and Straits Pond; and 4) greenish-gray, partly amygdaloidal flows, some having pillow structures and others being highly fragmental, and enclosing beds of greenish-gray tuff and minor dark-red tuffaceous shale; these flows are exposed on Atlantic Hill and along the shore from Long Beach Rock to the west end of Crescent Beach.

There are many dikes in the Nantasket locality. In general the dikes are parallel to the faults, and although minor slips have occurred along one or both walls of some of them, substantial faults occur along only a few dikes. Most of the dikes seem to be related to the volcanic activity that produced the andesite flows; these dikes are older than the faults.

Features of Outcrops to be visited

Stop No. 1 is at a quarry on the east side of George Washington Boulevard and about 0.15 miles south of the bridge over Weir River. This quarry is



PRELIMINARY GEOLOGICAL MAP OF THE NANTASKET LOCALITY

SCALE 1:24,000

in coarse-grained, somewhat porphyritic granodiorite. Much of this rock is composed of irregular pink microcline phenocrysts in a greenish crystalline groundmass There are zones a few feet wide of purplish-red, finer grained granodiorite that has been partially granulated and then cemented with microcline and quartz; this granulated rock has some of the features of a mylonite, and its color is due to finely dispersed hematite. Some large irregular dikelike masses of light pink aplite are exposed on the quarry walls. A few dark-greenish-gray dikes are associated with the local volcanic rocks; one of these dikes exposed on the west wall of the quarry has been broken and displaced by a small fault.

Stop No. 2 is at a rocky point on Worlds End Estates in the north part of Hingham. This point forms the west shore of Weir River estuary. It is reached by going to the gate of Worlds End Estates at the north end of Martins Lane and then walking about one-half mile northeastward along either one of two trails. Bedrock along Martins Lane and the east side of Worlds End Estates to about 1,000 feet south of the north end of the rocky point is granodiorite. The topography and alignment of outcrops reflect the fault pattern. A northwesterly trending ridge crosses the rocky point about 1,000 feet south of its northern tip. The ridge is bounded on the north and southwest sides by faults; that along the north side is one of the major faults of the Nantasket locality, and its downthrown side is to the north. Outcrops southwest of the ridge are granodiorite, with a few remnants of reddish arkosic sandstone resting upon it. Granodiorite forms a steep cliff at the west end of the ridge. The unconformable contact between granodiorite and a conglomerate-agglomerate bed that is the local basal unit of the Boston Bay Group can be seen near the west end of the ridge. The sedimentary rocks dip eastward, and eastward along the ridge they are overlain by the highly altered lower volcanic flow of the Nantasket volcanic rocks. Near the east shore of the point the volcanic rock is overlain by an agglomerate bed; at this place the strata have been displaced by some small subsidary faults, and there is a large dike associated with the Nantasket volcanic rocks. North of the ridge, stratigraphically higher units in the Boston Bay Group are exposed because of the substantial downward displacement of this block along the major fault that bounds the ridge. The fault is seen best at the west shore of the point. The downfaulted block is part of the northwest limb of a northeasterly plunging syncline; consequently the stratigraphically lower units are exposed at the north end of the rocky point. The lower units are amygdaloidal andesites, part of the third group of flows of the Nantasket volcanic rocks; they are overlain by conglomerate and agglomerate units.

Stop No. 3 is at sea cliffs on the Cohasset shore about half a mile east of Black Rock Hotel and Black Rock Beach. The cliffs are composed of granodiorite that contains orientated xenoliths of amphibolite. The granodiorite is conspicuously green owing to an abundance of chlorite and has a foliated texture paralleling that of the amphibolite xenoliths. Several dikes that are

associated with the Nantasket volcanic rocks are exposed in the cliffs

Stop No 4 is on the shore near Green Hill Rock A breakwater connects a large conglomerate outcrop on the shore and Green Hill Rock The conglomerate is composed mainly of wave-worn cobbles and boulders Green Hill Rock which can be reached by walking along the breakwater is composed of porphyritic andesite of the second group of flows of the Nantasket volcanic rocks

Stop No 5 is at sea cliffs on the shore about 750 feet east of Long Beach Rock These cliffs are composed of andesites and minor interlayered tuffaceous units belonging to the fourth or uppermost group of the Nantasket volcanic rocks Interesting features at this outcrop are pillow structures volcanic bombs and deposition of minor secondary quartz and calcite in the volcanic rocks

Stop No 6 is at Long Beach Rock and Atlantic Hill near the southeast end of Nantasket Beach Rocks at this place are on the northeast limb of the syncline and dip southeastward The uppermost unit is andesite of the fourth group of flows and is exposed on Atlantic Hill it is the highest stratigraphic unit of the Nantasket locality The lowest unit exposed here is tuffaceous conglomerate and agglomerate at the north edge of Long Beach Rock and can be seen only at low tide In the upper part of these sedimentary rocks is a bed of tuffaceous red sandstone and a bed of banded greenish porcelareous shale both about a foot thick. these thin beds display intricate brecciation and miniature faulting that occurred before the sediments were completely lithified The sedimentary rocks are overlain by rather fine-grained dense andesite of which a thickness of about 60 feet is exposed Long Beach Rock is separated from the mainland by a narrow shingle beach The cliffs at the north base of Atlantic Hill are composed of bedded tuff containing considerable coarse fragmental volcanic material especially in the upper part of the unit a thickness of about thirty feet of this unit is exposed Above this tuff are rather thin lenticular beds of andesite and tuff and finally a thick layer of andesite that forms most of Atlantic Hill

TRIP H

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